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Cultural Practices for Sorghums and Miscellaneous Field Crops

at the Southern Great Plains Field Station
Woodward, Okla.

Circular No. 959

UNITED STATES DEPARTMENT OF AGRICULTURE

In cooperation with the Oklahoma Agricultural Experiment Station

Cultural Practices for Sorghums and Miscellaneous Field Crops

at the Southern Great Plains Field Station, Woodward, Okla.

by

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and
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Agricultural Research Service

United States Department of Agriculture
in cooperation with
the Oklahoma Agricultural Experiment Station

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Cultural Practices for Sorghums and Miscellaneous Field Crops

at the Southern Great Plains Field Station, Woodward, Okla.

By L. F. Locke, soil scientist, and O. R. Mathews, senior agronomist, Soil and Water Conservation Research Branch, Agricultural Research Service [1]

Tillage and crop-rotation work with the major crops of the area was started at Woodward, Okla., in 1914 and was continued until 1948. This circular presents the results of tillage and rotation experiments with sorghums and other field crops, undertaken to determine the best tillage methods and cultural and fertility practices for these crops. Although the experiments discussed are limited to Woodward County, the crops and conditions are typical of western Oklahoma and the adjacent sections of other States, the area represented by the Southern Great Plains Field Station. The recommended cultural practices are considered suitable for that area.

Tillage and rotation experiments with wheat are fully covered in a previous publication (*8*).[2]

Crops Grown in the Area

The importance of the various cultivated crops in the area and the acreage changes that took place in 50 years (1899–1949) are illustrated by the census figures for Woodward County (table 1). These data give a general idea of the trends but not the wide annual or short-period variations of certain crops. These variations were caused by numerous factors, including climatic conditions, acreage limitations, price supports, increasing use of mechanical power, and economic conditions.

The annual acreages of several important annual crops during the period for which county data are available (1919–51) are shown (fig. 1). Data on which this figure is based were abstracted from the literature (*1*, *2*).[3]

Next to wheat, sorghums are the most important crop; and sorghums and wheat together usually occupy about 90 percent of the cropped land. The acreage of sorghums depends somewhat on that of wheat. When the acreage of wheat is low because of seeding restrictions, poor conditions at seeding time in the fall, or other causes, some of the land normally seeded to wheat is usually planted to sorghums.

Sorghums for grain and forage are the foundation of the livestock industry in the area, and grain

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[1] For one or more years, each of the following acted as project leader in charge of experiments conducted at Woodward and described in this circular: L. F. Locke, J. F. Brandon, E. F. Chilcott, H. J. Clemmer, J. E. Smith, O. R. Mathews, C. W. Brittain, V. C. Hubbard, and John Brenner. Mr. Brenner directed the field operations for most of the years during which the experiments were in progress.

[2] Italic numbers in parentheses refer to Literature Cited, p. 44.

[3] Certain data used in the figure were also abstracted from unpublished processed reports issued by Okla. Crop and Livestock Rptg. Serv.

Table 1.—*Acreage changes for certain principal field crops during 50 years, 1899–1949,*[1] *Woodward County, Okla.*

Crop	Year reported and number of harvested acres								
	1899	1909	1919	1924	1929	1934	1939	1944	1949
Corn	13, 981	92, 064	18, 781	25, 467	29, 094	6, 635	9, 824	2, 962	3, 018
Grain sorghum	687	22, 282	52, 345	34, 214	26, 826	22, 532	18, 592	32, 284	17, 493
Forage sorghum	15, 853	19, 251	23, 110	14, 087	18, 723	25, 538	20, 477	30, 146	19, 404
Broomcorn		13, 251	5, 034		4, 919		880		1, 255
Wheat	2, 259	27, 196	130, 423	124, 246	154, 703	95, 876	116, 198	149, 335	148, 690
Oats	234	4, 562	8, 100	3, 705	3, 137	1, 455	3, 574	7, 612	2, 300
Barley	19	155	1, 533	3, 383	899	1, 538	10, 335	8, 798	644
Rye	205	215	6, 654	2, 573	1, 049	1, 609	11, 043	3, 005	583
Cotton	10	533	21	254	2, 701	3, 801	431	50	51
Peanuts	37			5	32	48	5	19	17
Alfalfa	355	2, 910	3, 006	3, 031	2, 963	3, 374	2, 429	4, 852	6, 528
Sweetclover	20		178		3, 690	61	127	(2)	(2)
Cowpeas	1		350		235	469	361	97	806
Grain cut for hay	8, 743	814	902	852	297	790	1, 169	738	518

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[1] Data are from U. S. Bureau of the Census reports of harvested acres for the years indicated.

[2] Sweetclover was not included as a separate report in U. S. Bureau of the Census reports for 1944 and 1949.

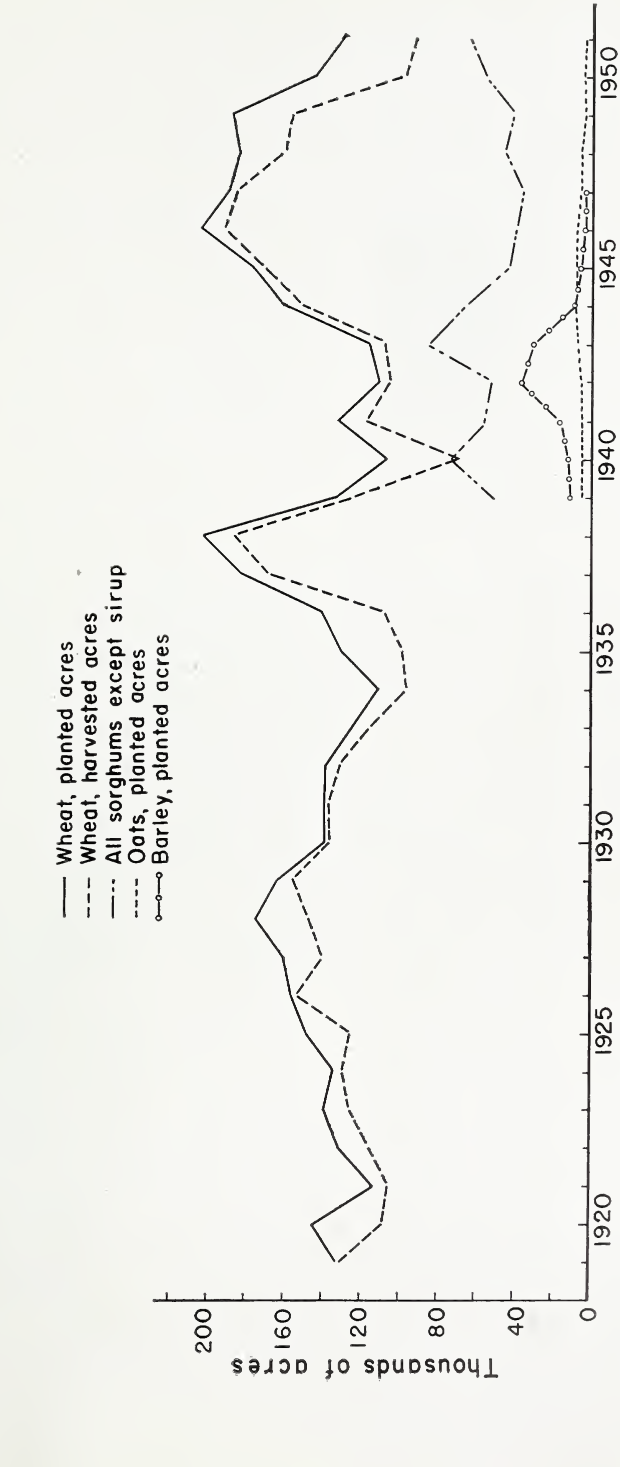

Figure 1.—Annual planted and harvested acres of wheat and planted acres of other important crops, Woodward County, Okla., 1919–51.

sorghums are a cash crop with many farmers. The relative amounts of grain and forage sorghums have not changed greatly during the years, but in recent years there has been a trend away from dual-purpose types to varieties grown primarily for either forage or grain. A large portion of the grain sorghums is now harvested with a combine.

Broomcorn, also a sorghum, was important in the county at one time, but its acreage has dwindled and only an extremely favorable price situation could reverse the trend. Like most crops that require considerable hand labor, broomcorn has suffered from competition with crops whose production is mechanized more completely, not only in this county but over the area as a whole.

Corn was an extremely important crop in the early years, and in 1909 it occupied more than 90,000 acres. The greater productiveness of the sorghums, particularly in severe drought years, has reduced corn acreage to a low figure.

Small grains other than wheat, such as rye, oats, and barley, may be used for either grazing or grain, or both. Winter rye is the only one of these represented in the tillage and rotation tests. Its responses to various tillage practices were found to be similar to those of wheat (*8*). Acreages of rye and oats were never particularly high but they have remained fairly constant (fig. 1). Barley showed an outstanding increase in acreage in the early forties (fig. 1). A combination of causes was responsible for this, the most important being the reduction in wheat acreage and the wider use of barley varieties that were more winter hardy than those previously available. Removal of acreage restrictions on wheat as well as damage to barley from greenbugs and winterkilling caused an equally rapid decline beginning in 1944. By 1946 the acreage had become so low that county statistics on barley were dropped by the Oklahoma Crop and Livestock Reporting Service, and figures on annual acreages were no longer available after that date.

Alfalfa acreages showed relatively little fluctuation (table 1), but these increased gradually, especially in the 10 years, 1939–49. Alfalfa is well adapted to bottom land and second bottom land, but much of the increase in acreage was on uplands where one or two cuttings of hay per year could often be obtained. Alfalfa is also harvested for seed and the aftermath generally used as pasture. It is not adapted to short-time upland rotations and has not been included in the rotation and tillage tests discussed in this circular.

Cotton growing, confined chiefly to the southern edge of the county, fell to a low acreage figure (table1). The crop was represented in tillage and rotation experiments on the station by a single plot in each of two fields.

Sweetclover was tried in occasional rotation experiments, but difficulty in obtaining or retaining stands during severe seasons greatly restricted its usefulness. The same experience on the part of farmers is reflected in the acreage figures (table 1).

Cowpeas were used rather extensively in rotations because they are well adapted to that type of cropping. The county acreage was never large, but it remained more constant than that of any legume hay except alfalfa.

Other crops, such as peanuts, Austrian winter peas, hairy vetch, and grasses, were used to some extent in crop rotations. The acreage reseeded to native or introduced grasses in the county, chiefly for use as pasture, increased greatly in the later years of the study. Rotations involving pastured grasses did not prove practicable in the experiments, while those involving harvested grasses were of too short duration to provide definite information as to their longtime effects.

Climatic Conditions

Crop production in any dryland area is determined to a considerable extent by climatic factors. The factors recorded at the Woodward station were precipitation, evaporation, temperature, wind velocity, and humidity. The data are summarized (table 2). Correlations of some of the climatic factors with sorghum yields are set forth later in this circular.

Precipitation

Rainfall is the most important single climatic factor in determining the yields of crops in the area represented by the Southern Great Plains Field Station. The amount and distribution of precipitation determine the quantity of water available to crops at critical periods of their growth and have a decisive effect on crop production.

The average distribution of rainfall is shown (fig. 2). The relatively low precipitation in mid-July may be one reason why most sorghums grow better when planted about June 15 or later than when planted considerably earlier (*3*, *9*, *10*). When sorghums are planted about the middle of June, the period of

TABLE 2.—*Monthly, total or average, and annual precipitation, mean temperature, wind velocity, evaporation, and relative humidity, Southern Great Plains Field Station, Woodward, Okla., 1915–48*

Item	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Seasonal total or average, Apr.–Sept.	Annual total or average
Precipitation__inches__	0.74	0.89	1.46	2.55	3.52	3.02	1.95	2.41	2.64	2.44	1.32	0.82	16.09	23.76
Mean temperature degrees F__	34	39	47	57	66	77	82	81	72	60	46	36	73	58
Wind velocity miles per hour__	7.0	7.9	9.0	8.8	7.2	7.2	6.6	6.2	7.0	6.6	6.9	6.8	7.2	7.3
Evaporation___inches__	-------	-------	-------	6.21	7.43	9.37	10.89	9.86	7.52	-------	-------	-------	51.28	-------
Relative humidity percent__	-------	-------	-------	55.0	58.9	56.3	51.2	53.0	56.8	-------	-------	-------	55.20	-------

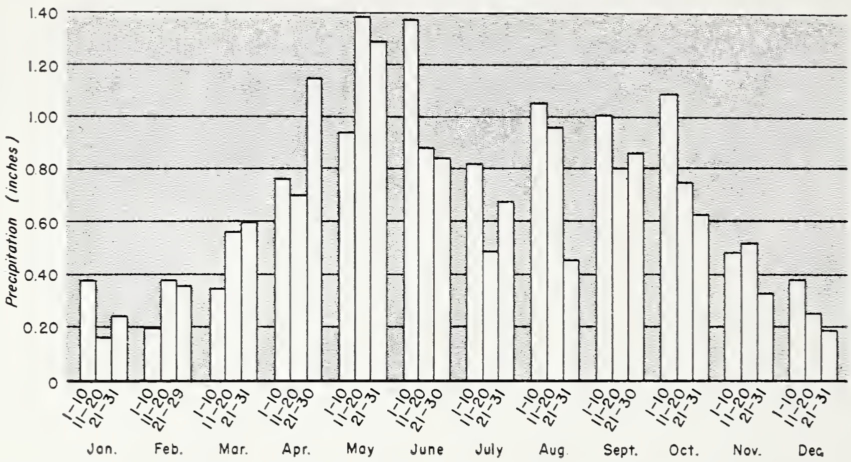

FIGURE 2.—Average precipitation by 10-day periods (average of 34 years' records), Woodward, Okla., 1915–48.

heaviest precipitation is over, and considerable moisture storage has usually been attained before the seed is planted. The crop does not reach the critical heading period until after the relatively heavy rain that can usually be expected August 1–20 (fig. 2).

Both the annual and monthly rainfalls are subject to wide variation. (For detailed data, see table 17, Appendix.)

Evaporation

The rate of evaporation has an important effect on crop production by modifying the quantity of water needed to keep crops in good growing condition. Evaporation is a result of the combined effect of temperature, wind velocity, and humidity. The average monthly evaporation is shown in table 2 and the detailed monthly data in table 18, Appendix.

Temperature

Mean temperatures for the different months are given (table 2). High temperatures result in greater use of water by crops and may be disastrous when low precipitation has reduced the water in the soil. Excessively high temperatures may damage crops, however, even when soil moisture is ample. (For a detailed tabulation of monthly temperatures, see *appendix table 24 of citation 8*.)

The dates and temperatures of the last spring frosts and the first fall frosts, based on readings of 32° F. or lower, are given (table 19, Appendix). The average date of the last spring frost is April 9. This is much earlier than the optimum planting time for most row crops, and crops such as sorghums are in no danger from late spring freezes. The first frost in the fall is much more important. It determines how late in the spring crops can be planted without danger from fall-frost injury, and also determines whether crops whose development has been delayed by drought or other cause can mature without damage. The average date of the first frost in the fall is October 27, but the annual date has ranged from October 10 to November 15.

The average frost-free period is 201 days.

Wind Velocity

Mean wind velocities are also shown (table 2). The highest average velocities are in the spring before most row crops are planted. Newly emerged sorghum crops are sometimes damaged by high winds that occur shortly after dashing rains have smoothed the soil to such an extent that soil movement can take place. Under such circumstances, the condition can usually be controlled by cultural operations, but in some instances damage occurs before these are possible. Mature crops are sometimes lodged by high winds, but this has occurred less frequently since dwarf grain sorghum varieties have come into general use. Land from which sorghums or other row crops have been harvested is susceptible to erosion from blowing, but this can usually be controlled through proper management practices. These practices are discussed in the literature. (See *4*.) An indirect effect of wind velocity is increased evaporation resulting in greater use of water. (For a detailed compilation of monthly wind velocities, see *appendix table 25 of citation 8*.)

Relative Humidity

Relative humidity is closely related to temperature and rainfall. Accordingly, at critical periods, humidity is associated with crop yields. Monthly relative humidities are given (table 20, Appendix). Those for July and August are most important to this study because that is the time of rapid growth of row crops.

Experimental Conditions and Procedures

Description of Experimental Fields

Rotation and tillage experiments were conducted on 2 fields, A and B. These fields differ in soil type and in their presumed adaptation to row crops. Field A is much the sandier of the 2 and contains by far the greater number of sorghum plots—about 80 compared to 24 in field B. Field A varies considerably in slope, soil, and general productiveness; therefore comparisons for this field as a whole are not feasible. Comparisons for field A are necessarily restricted to groups of plots on land more homogeneous than the field as a whole. A diagram of the plot layout of this field is given (fig. 3). (For specific locations and crop rotations within the field, see also table 3, p. 11). Even within the groups used in this study, there is considerable experimental error; and small differences should be discounted except where they are supported by results from other comparable treatments.

Field A was broken from native sod in January 1914, and crops were grown that year on uniformly prepared land. Rotation and tillage experiments were started in 1915. The field is on rolling land consisting of Pratt fine sandy loam and Pratt loamy fine sand.

An erosion survey describes the soils in field A as having a high infiltration rate, but recent tests indicate that infiltration through the first foot of soil is slow. Olmstead,[4]

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[4] Unpublished data compiled by L. B. Olmstead, formerly with the United States Bureau of Plant Industry, Soils, and Agricultural Engineering and located at Manhattan, Kans.

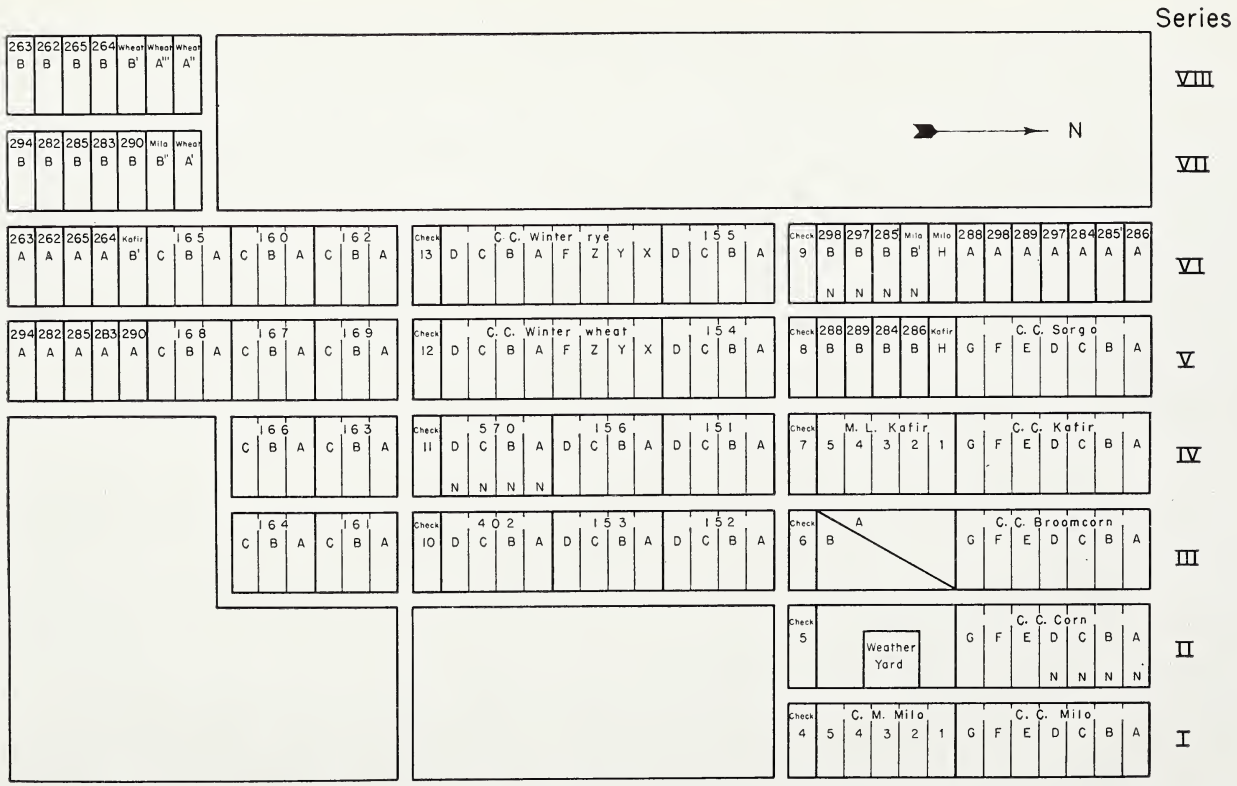

Figure 3.—Plot arrangement in field A. Rotations are indicated by number, and the plots in the rotation by as many letters as there are years in the rotation. Continuous-cropping and tillage experiments are indicated by crop names, and the plots are either lettered or numbered.

working in the laboratory with undisturbed 3-inch cores from different depths of plots cropped annually to milo, found that water penetrated through the 1½- to 4½-inch section of soil at the rate of approximately 0.3 inch per hour. Penetration through the 7½- to 10½-inch section was somewhat more rapid (about ¾ inch per hour). At the 16½- to 19½-inch depth, the rate of penetration was over 8 inches per hour. Olmstead also found that manuring a plot annually at a low rate (2½-tons per acre) for a period of 30 years had not caused any measurable change in the physical or moisture relations compared with those recorded for a plot similarly cropped but receiving no manure or other soil amendment.

Locke and Bull,[5] working with an infiltrometer on other plots in the same field, found evidence of a compact layer, or plow sole,[6] at depths of 4 to 8 inches. Penetration from an infiltrometer placed on the surface above this layer occurred at rates from 0.2 to 0.3 inch per hour. When surface soil was removed and the infiltrometer was placed at a depth of 8 inches, penetration was at the rate of about 9 inches per hour. These results agree substantially with those of Olmstead. It was also observed in this field that a single cultural operation while the soil was wet sometimes created a compact layer.

One peculiarity of this soil is that if it is worked while it is too wet, it tends to bake or crust so hard beneath the surface mulch that root penetration is almost impossible (fig. 4). This is because downward root development is checked temporarily until the crust is softened by rain or other moisture.

Field B consists chiefly of a soil similar to Grant silt loam, with small areas covered by Pratt fine sandy loam and Weymouth very fine sandy loam. A small tract of Pratt loamy fine sand also occurs in this field, but this was used for experimental work for only a short period.

The field has a general slope to the northeast. A small portion of the upper part has slopes up to 6 percent but most of the field has 1 to 3 percent slopes. The more level part has suffered slight sheet erosion, and the steeper portion has shown rather severe damage in roads and in other places where runoff water has been concentrated.

When the tract was acquired, this field was partly in native grass pasture and partly in cropped land. The appearance of the growing sorghums showed no effects of previous cropping. The field was originally acquired primarily for wheat experiments; therefore the number of sorghum plots was small.

Permeability studies by Olmstead[7] showed that the 1½- to 4½-inch section of soil permitted water to pass through at the rate of about ¾ inch per hour. Results from lower depths were variable, but they indicated that penetration through the 7½- to 9½-inch depth was about 3 times as rapid as in the same layer in field A. The penetration rate for the 16½- to 19½-inch depth was considerably higher than for sections nearer the surface.

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[5] Unpublished field tests by Locke and Bull. A. D. Bull, employed by the Soil Conservation Service, was formerly located at Woodward, Okla. He designed the infiltrometer used in this study.

[6] Called "plow sole" in accordance with common usage, although often present in land tilled with implements other than the plow.

[7] Unpublished experiments conducted by L. B. Olmstead.

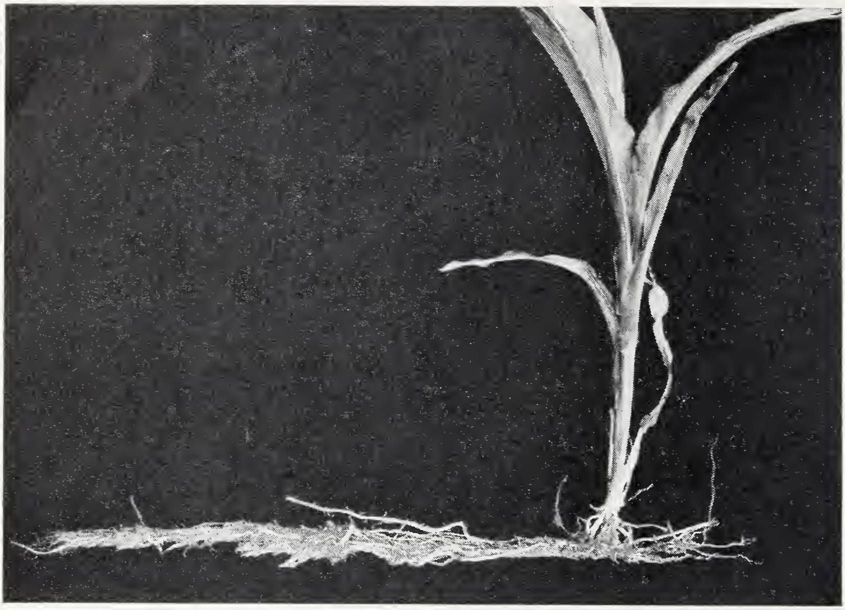

FIGURE 4.—A hard crust below the surface mulch prevented roots from developing beyond the depth reached by the planter shoe.

Plot Size and Arrangement

The standard size of field plots was 2×8 rods, or 0.1 acre. Plots were separated at the sides by alleys and at the ends by 20-foot roads. In most years plot size was reduced because the outside rows, which often show a border effect, were not harvested as a part of the plot.

Each cropping system or rotation contained as many plots as there were years in the system; thus, each crop and each tillage method was represented every year. Comparable rotations were generally laid out in blocks, and comparisons within such blocks are more accurate than comparisons for whole fields.

Only a few treatments were actually replicated, but there were enough treatments of a similar nature so that in effect most of them were replicated.

Rotation and Tillage Methods

Marked changes were made in 1918, when crops unsuited to the area were eliminated from the rotations and many new rotations were set up. Most of the usable crop-rotation comparisons began in 1919. The tillage methods, rotations, and crops for field A are given in detail (table 3). (See also fig. 3 for plot locations.)

Tillage Treatments and Planting

Treatments that were alike as to time of initial tillage operations were completed on the same day insofar as possible. Care was taken to eliminate all variables other than those being tested. Tillage variables were confined to the period of seedbed preparation and planting. After crops were planted, the land was kept nearly weed-free with tillage implements suitable to the

Table 3.—*Sorghums and other crops included in tillage groups and rotations in field A, and treatments used on the various experimental plots*

Crops	Treatment	Plot designations	Tillage group or rotation number
CONTINUOUSLY OR ALTERNATELY CROPPED			
Milo, corn, kafir, broomcorn, sorgo.	Spring-plowed	A	[1] C. C.
Do	Fall-plowed	B	[1] C. C.
Do	Fall-plowed and subsoiled [2]	E	[1] C. C.
Do	Listed	F	[1] C. C.
Do	Disked and listed	G	[1] C. C.
Do	Alternately cropped and fallowed.	C or D	[1] C. C.
Milo, kafir	Fall-plowed, manured	H	
Do	Fall-plowed	B′ [3]	
Milo	do	B′′ [3]	
Do	Cultivation methods	1 to 5	[4] C. M.
Kafir	Methods of listing	1 to 5	[5] M. L.
2-YEAR ROTATIONS			
Corn, winter wheat	Fall-plowed for corn	A, B	262
Milo, winter wheat	Fall-plowed for milo	A, B	263
Kafir, winter wheat	Fall-plowed for kafir	A, B	264
Cowpeas, winter wheat	Fall-plowed for cowpeas	A, B	265
Corn, kafir	Spring-plowed for both crops	A, B	282
Peanuts, kafir	Spring-plowed for peanuts; spring-plowed or cultivated for kafir.	A, B	283
Kafir, cowpeas	Spring-plowed and topdressed for kafir only.	A, B	284
Do	Spring-plowed for both crops	A, B	285
Do	do	A, B	[3] 285′
Do	Cowpeas plowed under	A, B	286
Kafir, fallow	Manured fallow	A, B	288
Do	Topdressed for kafir	A, B	289
Kafir, cotton	Spring-plowed for both crops	A, B	290
Milo, kafir	do	A, B	294
Milo, fallow		A, B	297
Do	Manured fallow	A, B	298
3-YEAR ROTATIONS			
Kafir, kafir, cowpeas	Spring-plowed for all crops	A, B, C	160
Milo, kafir, cowpeas	Fall-plowed for all crops	A, B, C	161
Milo, kafir, cowpeas	Spring-plowed for all crops	A, B, C	162
Kafir, milo, cowpeas	Fall-plowed for all crops	A, B, C	163
Winter wheat, winter wheat, cowpeas.	Fall-plowed for 2nd wheat crop and for cowpeas.	A, B, C	164
Milo, kafir, fallow	Spring-plowed for kafir	A, B, C	165
Winter wheat, milo, cowpeas	Fall-plowed for milo; spring-plowed for cowpeas.	A, B, C	166
Winter wheat, kafir, cowpeas	Fall-plowed for kafir; spring-plowed for cowpeas.	A, B, C	167
Kafir, milo, fallow	Spring-plowed for milo	A, B, C	168
Kafir, milo, cowpeas	Spring-plowed for all crops	A, B, C	169

See footnotes at end of table.

TABLE 3.—*Sorghums and other crops included in tillage groups and rotations in field A, and treatments used on the various experimental plots*—Continued

Crops	Treatment	Plot designations	Tillage group or rotation number
4-YEAR ROTATIONS			
Kafir, fallow, wheat, winter rye.	Rye plowed under	A, B, C, D	151
Kafir, corn, wheat, winter rye.	Corn in 88-inch rows; rye plowed under.	A, B, C, D	152
Wheat, corn, kafir, winter rye.	do	A, B, C, D	153
Kafir, fallow, wheat, Canada field peas.	Peas plowed under	A, B, C, D	154
Kafir, fallow, wheat, fallow		A, B, C, D	155
Do	Manured fallow following wheat	A, B, C, D	156
Kafir, fallow, wheat, kafir		A, B, C, D	402

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[1] C. C. indicates plots A to G only of the original continuous-cropping and alternate-cropping groups.

[2] Spring-plowed after 1940, except for corn.

[3] 1 mark (′) on a capital letter or a number means 1 replication of the C. C. plot designated by that letter or the rotation designated by that number; 2 such marks mean 2 replications.

[4] C. M. indicates 5 plots cultivated by different methods.

[5] M. L. indicates 5 plots listed by different methods.

planting method. Murphy (*11*) and others have shown that when row crops are kept free from weeds, wide differences in methods of summer cultivation result in little or no difference in yield.

Statistical Evaluation of Yield Data

Although the plot layouts were not designed for complete statistical analysis, plots in some rotations were randomized. Owing to soil variations, many of the treatments could be compared only with those of nearby plots. Data were confirmed by records of cropping over a long period of years rather than by plots, rotations, tillage methods, and cultural practices replicated in any one year. It would therefore be impossible to separate the variation caused by soil from that caused by treatment. However, experiments with four different sorghums provided partial duplication or replication.

Most yield data were subjected to an analysis of variance, and the treatment-by-years interaction was used as a measure of experimental error. The least significant differences (L. S. D.), used for comparing treatments or tillage practices, were based on this error term. In the following discussion of results, the L. S. D.'s are given for information.

Results

Sorghums

Sorghums grown in these tests were of three general types: Those grown primarily for grain; those grown primarily for forage; and broomcorn, which is grown mainly for the brush. The grain sorghums (milo and kafir in these experiments) were grown in a wide variety of cultural rotation experiments in both fields. Forage sorghum and broomcorn were grown in the continuous-cropping series only. Detailed yields of the different sorghums are given in tables 21 through 28, Appendix.

Intensive work in sorghum breeding, extensive variety testing, date and rate of planting trials, and other studies were made at this station. Many of these investigations are reported in the literature (*3*, *5*, *6*, *9*, and *12* through *16*); and sorghum diseases are fully discussed (*7*).

Continuous-Cropping Experiments With Milo, Kafir, Broomcorn, and Sorgo

The 4 crops mentioned were grown (1915–48) in a block of plots at the northern end of field A. A view of these plots after the corn had been harvested is shown (fig. 5). Each crop was represented by 5 plots cropped continuously by different methods of tillage, and 2 plots alternately cropped and fallowed. The tillage treatments and average yields are given (table 4), together with the difference required for significance at the 5-percent level. As explained on p. 12, this test of significance does not distinguish between the variation caused by soil and that caused by treatment. The lack of precision of such an estimate of error is brought out in this group of plots.

After the experimental work on these plots was discontinued in 1948, the plots were handled uniformly and planted to a grain sorghum. It was assumed that the soil in plots that had grown the same variety of the same crop each year would not have become greatly differentiated; therefore the yields shown in table 4 were later adjusted in accordance with yields from the same group of plots in 3 years of uniform cropping. This adjustment (not shown in the table) removed most of the small but consistent advantage of fall plowing over spring plowing. The seemingly significant difference in favor of plowing, over cultivating in the early spring and then planting with a lister, also disappeared. On the other hand, the difference in favor of

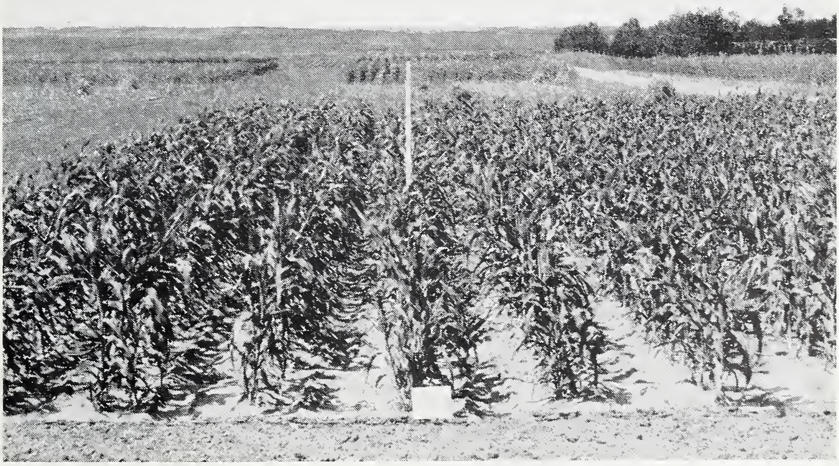

Figure 5.—View of milo plot B in C. C. groups, showing corn, kafir, broomcorn, and sorgo in background.

TABLE 4.—*Average yields of milo, kafir, broomcorn, and sorgo in continuous-cropping experiments, Woodward, Okla., 1915–48*

Tillage treatment	Plot designation	Average yields per acre of—					
		Milo grain	Kafir		Broomcorn		Sorgo, total weight
			Grain	Stover	Brush	Stover	
		Bushels	*Bushels*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Spring-plowed	A	16. 7	19. 8	3, 017	334	2, 686	5, 331
Fall-plowed	B	18. 4	20. 9	3, 124	326	2, 686	6, 230
Fall-plowed and subsoiled	E[1]	16. 1	16. 8	2, 701	404	3, 172	6, 561
Planted with lister; no prior cultivation	F	12. 2	12. 1	2, 106	350	2, 387	4, 765
Spring-cultivated; planted with lister	G	12. 3	14. 6	2, 232	444	2, 837	5, 816
Alternately cropped and fallowed	C or D	17. 8	22. 1	3, 582	374	2, 961	7. 425
L. S. D. at 5-percent level		1. 8	2. 0	247	36	198	497

[1] Spring-plowed after 1940.

cultivating well in advance of lister planting over lister planting without previous cultivation was greatly accentuated and is the one really significant difference. The condition of the 2 plots resulting from 2 methods of treatment shortly before planting is illustrated (fig. 6).

The effects of fallow with these crops are summarized as follows: It increased acre yields only slightly above the levels attained under good methods of production, and accordingly reduced by nearly one-half the quantity of sorghum that could be produced on a given acreage of land. In addition, as shown later (p. 40), it seemed to reduce the fertility of the soil to a greater extent than annual cropping.

The reason for lack of response to fallow is that during the long period between the harvesting of one crop and the time the next began to use water rapidly, the difference in moisture content between fallowed and cropped plots often almost disappeared.

In most years more water was taken into land being fallowed, during the 20 months that it was without a crop, than the soil was capable of holding. The leaching effect of this excess water may have been responsible for increased loss of nitrogen and possibly of other fertility elements.

Chemical analyses of soil samples taken on a portion of the continuously and alternately cropped plots at the end of the experiment (p. 62) showed a general but not close relationship between levels of nitrogen and carbon in the soil and yields under uniform cropping.

Tillage Methods for Milo

This experiment was conducted, 1921–48, on five plots located just east of the weather yard (fig. 3) and was started primarily to determine whether yields could be influenced materially by the method of seedbed preparation. The methods under trial were:

1. Kept free from weeds with a disk; shallow-listed at planting.
2. Kept free from weeds with a disk; surface-planted.
3. Early-spring-listed; cultivated; relisted at planting.

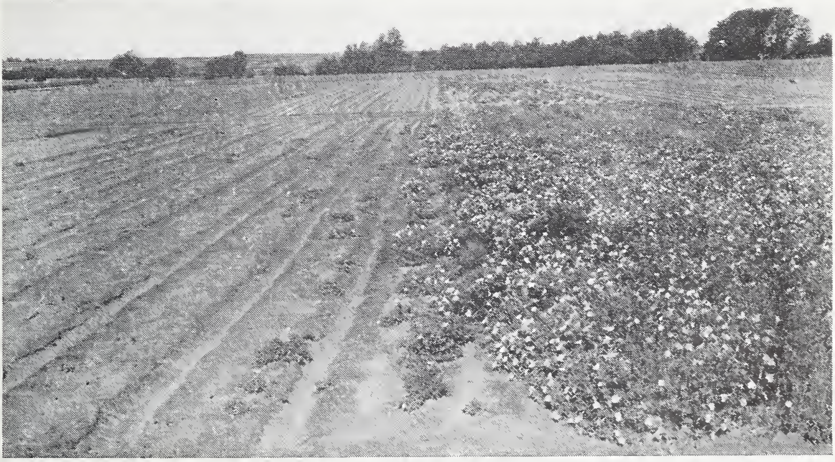

Figure 6.—View of plots F and G in C. C. groups before planting, showing differences in weed growth resulting from one disking at the time weeds started. (Disked plot shown at left; undisked plot at right.)

4. Early-spring-listed; harrowed; same furrows relisted at planting.
5. Early-spring-listed; ridges split with lister at planting.

This group seemed to contain enough variables to cover the prevailing methods of spring land preparation for sorghums. The results, however, were disappointing. All yields were at a common low level, with no method differing as much as a bushel from the general average. Method 3 was changed to spring plowing during the last few years of the experiment, but this did not change its yield in relation to those from other methods. Later, preliminary fertilizer experiments and detailed observations of deficiency symptoms in growing sorghum plants on this land showed that the soil was decidedly deficient in some fertility elements; this may partly account for its lack of response to cultural differences.

Tillage Methods of Fallow for Kafir and Broomcorn

This study was conducted on a group of plots immediately south of the location of the C. C. kafir and C. C. broomcorn plots, as shown on the present figure 3; however, the plots covered by this experiment were discontinued before figure 3 was prepared and therefore are not shown thereon. The object was to determine how much the yield would be influenced by the length of time the land was kept free from weeds. The methods and the average acre yields of kafir for 1915–36 are given (table 5).

The data indicate no advantage in starting cultivation earlier than June of the fallow year. These results are of theoretical rather than practical interest, but they show that the method of fallow used in the continuous-cropping experiments did not contribute to the poor showing of fallow.

A similar study with broomcorn, extending over a 6-year period (1915–20), showed similar results.

Listing Methods for Kafir, Field A

After the fallow experiment was discontinued in 1936, a replicated comparison of ordinary listing with basin listing was started. The results for 12 years showed a differ-

Table 5.—*Average yields of kafir grain and stover from 5 tillage methods for fallow, Woodward, Okla., 1915–36*

Tillage method for fallow	Plot designation [1]	Length of fallow period	Average yields per acre of—	
			Grain	Stover
		Months	*Bushels*	*Pounds*
Plowed after harvest, replowed in June	H, I	18	22. 5	3, 626
Plowed after harvest	J, K	18	20. 9	3, 519
Plowed in May	L, M	13	21. 3	3, 528
Plowed in June	N, O	12	24. 0	3, 892
Listed in May [2]	P, Q	13	22. 9	3, 951
L. S. D. at 5-percent level			1. 2	194

[1] The plot designations given here are not to be identified with those on figure 3, as this experiment was completed before figure 3 was prepared.

[2] This schedule was not always strictly adhered to, although it was in most years. In a few of the years, these plots were cultivated earlier than L, M, and in a few as late as N, O.

ence of 1.3 bushels in favor of basin listing, a difference of doubtful significance. This experiment further showed that basins on sloping land do not prevent runoff from heavy rains and may even increase erosion damage from such rains. When the basin lister is used on the contour, the dams are less likely to break, but the method has no apparent advantage over ordinary listing on the contour.

Listing Methods for Kafir, Field B

Since the soil of field B is heavier than that of field A, the differences resulting from tillage methods were expected to be more pronounced. An experiment was started that consisted of 5 listing methods and 1 plowing method. All plots except the plowed one were lister-planted. The methods used and the average resultant yields are shown (table 6).

The only method whose average yield differed markedly from that of the others was the early-spring listing, with ridges split at planting. The most interesting result of the experiment is not shown by the average-yield figure. During the period 1932–36, the surface-planted plot was plowed shortly before planting. During this period both the grain yield and the stover yield were lower than under any other treatment. In 1937 and subsequent years, plowing was done at the same time as spring-listing. During the period 1937–48, the grain and the stover yields of the plowed plot were both higher than under any other treatment. Thus, in this experiment as in the continuous-cropping tests, tilling well in advance of planting proved to be highly important.

Organic Soil Amendments Under Continuous Cropping and in Short Rotations

This study consisted of a group of short rotations and a number of continuously cropped plots. Its purpose was to determine the effect of manures on immediate yields and on the sustained productivity of the soil. It included comparisons of cropping with and without manure; a comparison between manure plowed under and manure applied as a topdressing; and a comparison between a legume

TABLE 6.—*Average yields of kafir grain and stover in methods-of-listing (M. L.) experiment, field B, Woodward, Okla., 1933–48*

Method of tillage	Average yields per acre of—	
	Grain	Stover
	Bushels	*Pounds*
Fall-listed, leveled, lister-planted by splitting ridges	19. 4	2, 824
Fall-listed, leveled, lister-planted by nosing out old furrows	18. 9	2, 671
Early-spring-listed, lister-planted by splitting ridges	16. 4	2, 612
Early-spring-listed, leveled, lister-planted by nosing out old furrows	19. 3	2, 727
Early-spring-disked, lister-planted	18. 1	2, 864
Spring-plowed, surface-planted [1]	18. 8	2, 921
L. S. D. at 5-percent level	2. 2	233

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[1] Plowed immediately before planting, 1933–36; plowed in early spring, 1937–48.

plowed under for green manure and the same legume harvested for hay.

The 2-year rotations were set up with the A plots in one group and the B plots in another, the plots being randomized within the groups to some extent. This had the effect of making average results less rather than more dependable.

The treatments and the average grain and stover yields for the different rotations are shown (table 7). Without exception, plots receiving manure produced considerably higher stover yields, but differences in grain yields were small or lacking. The data were further examined to determine whether the difference between the manured and unmanured plots changed with time. It was apparent that no such progressive change occurred with continuous kafir (fig. 7). Throughout the experiment, grain

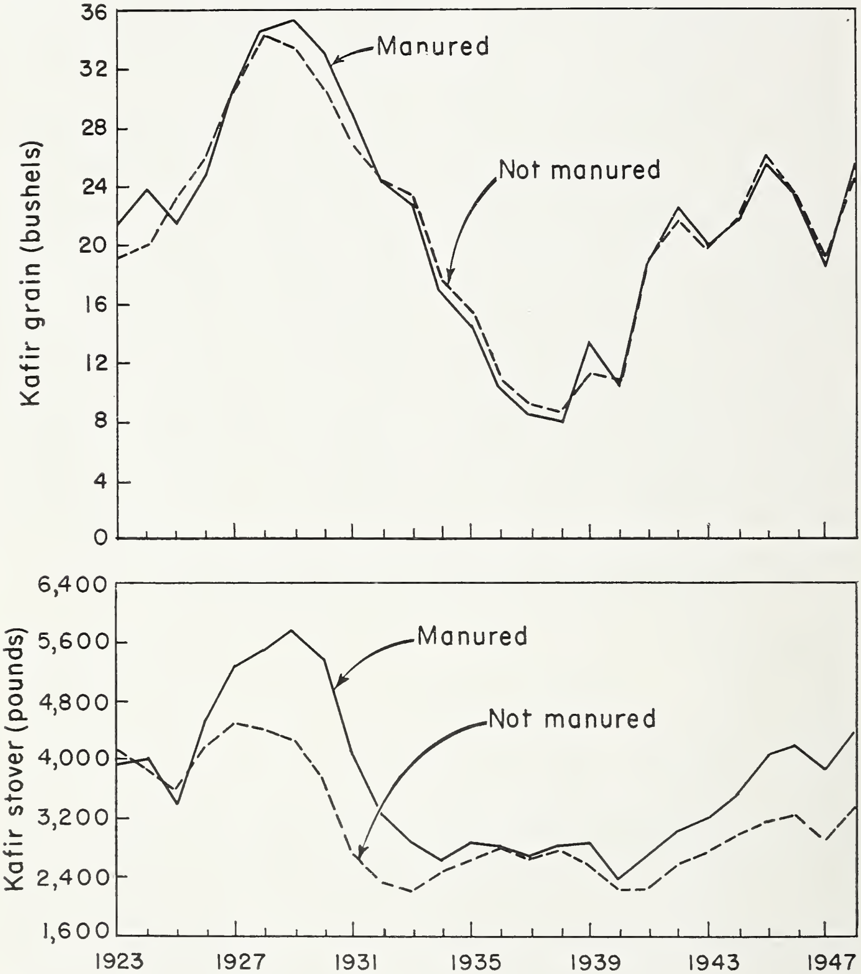

FIGURE 7.—Five-year moving averages of grain and stover yields of continuous kafir on manured and unmanured land, Woodward, Okla., 1919–48. (The average value charted for each year is the average annual yield for the 5-year period ending with that year.)

Table 7.—*Average yields in continuous-cropping and 2-year-rotation experiments with and without organic soil amendments, Woodward, Okla., 1919-48*

Treatment	Plot or rotation	Average yields per acre of—				
		Kafir		Cowpeas (total weight)	Milo	
		Grain	Stover		Grain	Stover[1]
Continuously cropped:		*Bushels*	*Pounds*	*Pounds*	*Bushels*	*Pounds*
Kafir, manured	H	22. 2	3, 801			
Kafir	B	21. 6	3, 281			
Milo, manured	H				13. 9	3, 555
Milo	[2] B′				15. 9	2, 875
2-year rotations:						
Kafir, topdressed; cowpeas	284	18. 9	3, 400	2, 050		
Kafir, cowpeas	[2] 285′	16. 5	2, 654	1, 755		
Kafir, cowpeas plowed under	286	18. 8	3, 017			
Kafir, manured fallow	288	19. 4	3, 444			
Kafir, topdressed; fallow	289	18. 3	3, 440			
Milo, fallow	297				14. 8	3, 126
Milo, manured fallow	298				14. 4	3, 798
L. S. D. at 5-percent level		1. 9	309		2. 0	513

[1] Milo stover yields are from 1919–31.

[2] 1 mark (′) on a capital letter or a number means 1 replication of the C. C. plot designated by that letter or the rotation designated by that number.

yields on the manured and unmanured plots were approximately equal in good and bad periods. During favorable years, stover yields were much higher on manured land, but there is no evidence that the spread between yields on manured and unmanured plots was any greater during the later years of the experiment than during a similar period of favorable precipitation in the late twenties.

It has been evident in recent years that in every instance since the differential treatments were discontinued and the plots uniformly cropped, the manured plots have produced higher grain yields and the plants have shown a better color than those on the unmanured plots.

It has been mentioned (p. 18) that difficulty in interpreting the data resulted from the randomization of the B plots. This is particularly true of the comparison between different rotations containing kafir and cowpeas. The A plots of the three rotations (284, 285′, and 286) are close together in series VI (see fig. 3). On the other hand, the B plots of rotations 284 and 286 are located in series V which, under uniform cropping, proved to be more productive than series VI where B plot 285′ is located (fig. 3).

During the 15 years that kafir in rotations 285′ and 286 occupied adjoining A plots, the yield difference in favor of 286 was only 0.4

bushel of grain and 160 pounds of stover, a difference too small to have much significance. However, during the years that kafir occupied the B plots, which are in different series, the average yield of rotation 286 exceeded that of 285′ by 4.2 bushels of grain and 566 pounds of stover. Part of this difference may have resulted from seasonal variations, since years of high production under a certain method have often occurred when that method was used on 1 of 2 alternate plots; but this was not the chief cause. The yields of cowpea hay in rotations 284 and 285′ support the conclusion that much of the difference on the B plots was due to location rather than seasonal variations. Cowpeas occupied the A plots when kafir occupied the B plots, and vice versa. The difference in cowpea yields was only 116 pounds per acre in favor of rotation 284 when the crop was on the A plots, but it was 475 pounds when the cowpeas were on the B plots that were in different series.

The time of applying manure had no effect on grain or stover yields. The results of applying manure as a topdressing to kafir following fallow were not significantly different from those obtained by applying it to land being fallowed for kafir.

Sequence Effects in 2-Year Rotations

The effect of different crops on each other was measured in 2 groups of 2-year rotations at the south end of field A (fig. 3) and in 1 group in field B. In group 1 in field A, kafir was common to all rotations. In group 2 in field A, and in the 5 rotations in field B, wheat was the common crop. Results are given (table 8).

In group 1, the yield of kafir following milo was materially lower than following any of the other four crops. In group 2 of field A, and in field B, wheat yields were much lower following kafir and milo than following corn or cowpeas. The single rotation with wheat following cotton in field B produced wheat yields lower than those following corn or cowpeas, but higher than those following sorghums. The drastic reduction in wheat yields following sorghums proves that it is inadvisable to grow wheat in that sequence.

The relative productivity of crops following kafir and wheat is roughly indicated in crop comparisons between the two groups in field A. Where comparisons could be made, it was found that all yields were higher after wheat than after kafir, except the yield of milo grain; and this exception was not significant.

Efforts were made to fit sorghums and wheat into a workable short rotation by growing the sorghum in rows 16½ feet apart. For this purpose, 2 varieties of milo—Dwarf Yellow and Wheatland (combine type)—were used. The behavior of these 2 varieties was markedly different. Dwarf Yellow milo benefited from the extra space between rows, but it materially reduced the yield of wheat that followed it. Wheatland milo did not benefit similarly from the wide spacing, but on the other hand, it did not reduce the yield of wheat to the extent that Dwarf Yellow did. The total yield of milo grain and wheat was almost exactly the same for the 2 rotations. It was lower than the quantity of grain that could have been produced by planting all the land to wheat, or all to milo in rows with ordinary spacing.

A further effort was made to produce sorghum for feed in a farming system directed primarily toward wheat production. The method was to plant short-season grain sorghums in wide-spaced rows as soon after wheat harvest as the land could be prepared. The practice

TABLE 8.—*Average crop yields in 2 groups of 2-year rotations in field A and 1 in field B, in experiments designed to determine the effect of sequence, Woodward, Okla.*

Field, group, and rotation	Average yields per acre of—										
	Kafir		Corn		Peanuts		Milo		Cowpea hay	Seed cotton	Wheat grain
	Grain	Stover	Grain	Stover	Nuts	Hay	Grain	Stover			
Field A:											
(1919–48):											
Group 1:	*Bushels*	*Pounds*	*Bushels*	*Pounds*	*Pounds*	*Pounds*	*Bushels*	*Pounds*	*Pounds*	*Pounds*	*Bushels*
282	20. 0	3, 117	8. 6	1, 603							
283	20. 8	3, 283			599	[1] 2, 214					
285	20. 5	3, 336							1, 946		
290	[2] 22. 1	[2] 3, 513								[3] 524	
294	17. 4	2, 749					18. 1	[4] 3, 258			
Group 2:											
262			9. 4	2, 016							18. 4
263							17. 2	[4] 3, 565			12. 5
264	21. 6	3, 478									13. 1
265									2, 220		18. 4
Field B:											
(1933–48):											
35			9. 3	2, 149							17. 2
124										548	14. 5
257							23. 2				12. 6
264	20. 0	3, 549									12. 2
265									1, 742		19. 4
L. S. D. at 5-percent level for—											
Field A	1. 9	289									2. 0
Field B											2. 8

[1] 29-year average, 1920–48.
[2] Kafir in this rotation followed Mexican beans, 1919–26; Jerusalem-artichokes, 1927–34; and cotton, 1935–48.
[3] 14-year average, 1935–48.
[4] 13-year average, 1919–31.

proved unsuccessful; sorghum yields were so low in all but a few years that the crop would not have paid for the harvesting. The average yield of sorghum grain produced after wheat harvest was approximately equal to the reduction in wheat yield that resulted from the practice.

Sequence and Tillage Effects in 3-Year Rotations

This group of ten 3-year rotations, numbered 160 to 169, was located in the south-central portion of field A (fig. 3). The rotations were designed chiefly to determine the crop sequence and time of plowing, with which milo, kafir, and cowpeas could best be combined in a rotation. In two of the rotations, fallow replaced cowpeas; and in three, winter wheat replaced one or both of the sorghum crops. Results are given (table 9).

Yield differences, especially between spring and fall plowing, are affected by location; but for all crops except cowpeas, spring-plowing results were inferior to those of fall plowing. Spring plowing was usually done 2 to 3 weeks in advance of planting. Even with the yield differences, fall plowing is not recommended because of the soil-blowing hazard. Results from the listed plots in the continuous-cropping series lead to the belief that some of the yield differences could be eliminated by earlier tillage of the spring-plowed plots.

In all direct comparisons that could be made, yields of crops following wheat were much higher than following sorghums and somewhat higher than following cowpeas. The difference is considerably greater than could be accounted for by location. This fact is supported by the data on yields in a rotation of cowpeas, wheat, wheat.

TABLE 9.—*Sequence and tillage results in a group of 3-year rotations Woodward, Okla., 1919–48*

Previous crop and tillage method	Average yields per acre of—				
	Kafir		Milo	Cowpeas	Wheat
	Grain	Stover			
Kafir:	*Bushels*	*Pounds*	*Bushels*	*Pounds*	*Bushels*
Spring-plowed	16.2	2,406	[1] 22.8	[2] 1,979	
Fall-plowed			24.7	1,970	
Milo:					
Spring-plowed	16.6	2,569		[1] 2,086	
Fall-plowed	21.8	3,134		2,088	
Cowpeas:					
Spring-plowed	[1] 20.8	[1] 3,190	19.5		
Fall-plowed	26.6	3,754	24.7		
Disked					[2] 19.0
Wheat:					
Fall-plowed	29.2	4,310	28.5	2,230	22.8
Fallow	25.9	4,020	23.2		
L. S. D. at 5-percent level	2.4	298	1.9	175	1.7

[1] Average of 2 rotations.

[2] Average of 3 rotations.

The yield of wheat following wheat was 2 bushels higher than that following cowpeas, although they were grown on the same group of plots and soil differences were not a factor.

Results from these rotations, as well as from the 2-year rotations previously discussed, demonstrate that production of crops following sorghums is likely to be depressed, regardless of the type of crop or the tillage method employed. Sorghums fit poorly into rotations with other annual crops, but sorghums are so much more valuable than most competing crops that they have an important place in any system of farming where production of feed for livestock is essential.

Yields on fallowed land in this group of rotations are relatively low, partly because of location. These rotations further demonstrate the fact that fallow for sorghums is not practical under such conditions as those at Woodward.

Effects of Organic Amendments in 4-Year Rotations

This group of rotations was designed to test the effects of organic soil amendments on the continued productivity of the soil. In order to minimize differences resulting from moisture conservation, all crops were grown following fallow or following a crop plowed under for green manure. The manure and green manure immediately preceded the kafir crop. The results with kafir are shown (fig. 8).

The absolute yields in these rotations, particularly rotation 155, are influenced to some extent by location. Differences resulting from amendments, however, were ex-

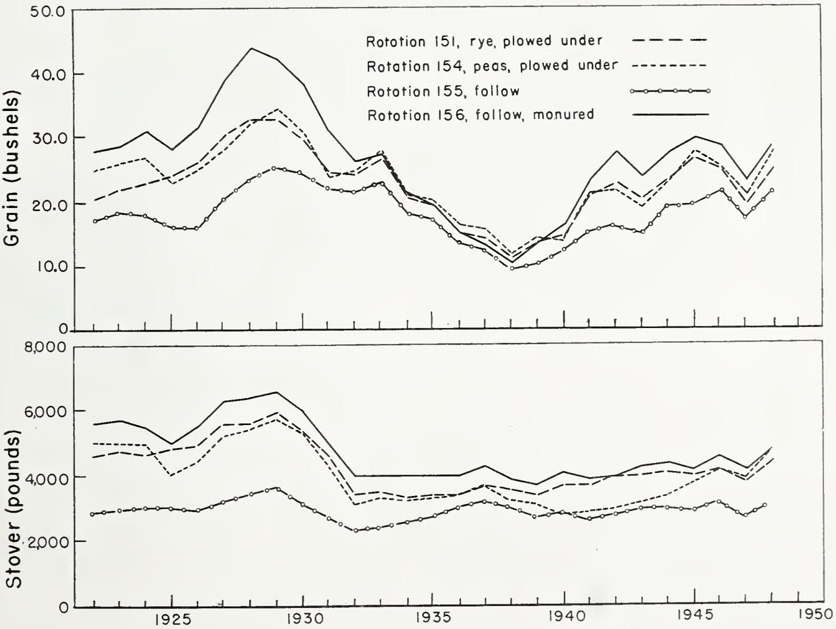

FIGURE 8.—Five-year moving averages of yields of kafir grain and stover in four-year rotations with and without organic amendments.

pected to be shown by an increasing spread between results from rotations in which they were used and results of the unmanured rotation. Such a spread, however, did not develop; the difference between results of the unmanured rotation and those receiving some organic amendment remained substantially the same throughout the experiment. This is in contrast to the results obtained with wheat, which was grown the second year after kafir in these rotations. With wheat, there was a widening spread in favor of the rotations with amendments. The residual effect apparently lasted at least 4 years after the amendment was applied. The failure of amendments to accentuate differences in relative yields of kafir in succeeding cycles of these 4-year rotations proves either that the residual effect did not last through more than 1 cycle of the rotation, or else that yields of kafir were limited by factors other than the nutrients supplied by the amendments.

The differences in grain and stover yields of kafir in favor of the manured over the unmanured rotation was greater in the early years of the experiment than in subsequent periods. The same held true with the green-manured rotations, although the margin of difference was smaller. This may have resulted from the fact that a taller variety of kafir was grown in the early years.

These organic-amendment studies furnish further evidence of the extent to which differences resulting from fertility are masked by seasonal differences resulting from climate. Actual yields seem to indicate that the yield levels of all rotations declined somewhat. An effort was made to determine whether there was a progressive change in yields. The July–August precipitation discussed later (p. 26) had an important bearing on sorghum yields; this was used as a basis for adjusting annual yields. After yields were so adjusted, there was no positive evidence that they were either increasing or decreasing. There was still enough variability resulting from other factors so that minor changes would have been unnoticeable.

Kafir in Miscellaneous 4-Year Rotations in Field A

Kafir was also grown in three 4-year rotations (152, 153, and 402) in the central section of field A. Two of these rotations were designed principally to test the effect of corn in double-width rows (see p. 34). Results with kafir in these rotations are summarized as follows: (1) The yield of kafir immediately following a green-manure crop was higher than on land where a harvested crop had been grown. (2) The yield after corn planted in double-width rows almost exactly equaled the yield following wheat. (3) The yield of kafir following kafir was materially lower than following wheat.

These results are similar to the sequence results obtained in the other groups of rotations discussed in this circular.

Miscellaneous Experiments in Field B

When the work in field B was started, it seemed desirable to determine whether a better response to fallow would be shown on that soil than on the lighter soil in field A. The increase in yield of fallow over continuous cropping was 3 to 4 bushels per acre. There was a little more response than in field A, but not enough to make fallowing advisable.

Several plots and checks were set up to determine the influence on yield of contour cultivation and planting. Average results given (table 10) indicate that contouring increased the yields of grain and stover. However, establishing contour-cultivation experiments on layouts not designed for them introduced difficulties. The results, while favorable to contouring, are not precise enough to be used as a measure of predictable average increases.

Fertilizers for Sorghums

It has been determined that most soils in this area are deficient in nitrogen. Fertilizer experiments with wheat have usually shown a response from both nitrogen and phosphorus. This work has been reported in the literature (*8*).

Limited fertilizer experiments with grain sorghums were conducted on both silt loam and sandy loam soils. In all trials with grain sorghums, nitrogen, when applied in sufficient quantity, gave a beneficial response. This response varied with climatic conditions from the growth of greener leaves with less nitrogen-deficiency symptoms to over 50-percent increase in yield of both grain and forage. Results can usually be expected to fall between these extremes. Required quantities of fertilizer vary with the soil; on sandy loam soils, more than 20 pounds of nitrogen per acre are normally needed to be effective.

Nitrogen fertilizer should not be applied directly on the seed. It may be applied broadcast, either before or after planting, but it is best applied along a parallel strip close to one side of each row and slightly deeper than the seed. Sidedressings of fertilizer, applied after the plants have attained about half their growth, also increased the yields.

Relations Between Climatic Factors and Yields of Sorghums

In semiarid areas there has always been an interest in year-to-year variations in crop yields resulting from weather conditions, and also a desire to determine which climatic factor is most responsible for these variations. This cannot be determined specifically because the factors are interrelated, but a study was conducted correlating the different factors with yield, and these are an indication of the extent to which any single factor may be used as a criterion.

The factors studied were: (1) Precipitation for different months and groups of months. (2) Evaporation for the critical months of July and August. (3) Relative humidity for the summer months. (4) Saturation deficit for July and August. Results with kafir and milo are presented (table 11). These correlations cover the whole group of

Table 10.—*Average yields of sorghums on contoured and noncontoured land, Woodward, Okla., 1937–48*

Crop and treatment	Contoured		Noncontoured	
	Grain	Stover	Grain	Stover
	Bushels	*Pounds*	*Bushels*	*Pounds*
Milo on fallow	25. 9	--------	23. 2	--------
Milo, continuous cropping	23. 9	2, 468	23. 7	2, 215
Kafir, continuous cropping	22. 7	3, 001	19. 1	2, 816

continuously cropped plots. Preliminary calculations showed little difference between the continuously cropped and the alternately cropped and fallowed plots. The correlations for milo are not representative of all the data obtained, but they are illustrative. Correlations for kafir were made for periods which results with milo indicated might be of interest.

The correlations with precipitation show that those for July and August are high and that the correlation for the 2 months combined is higher than for either month alone. The relationship between the July–August precipitation and yield is presented visually (fig. 9, *A*). Variations in precipitation are shown for a continuous period, 1885–1952; this includes the experimental period, 1915–48 (fig. 9, *B*). It is evident that the period covered by these experiments was less favorable for sorghums than was the average for all years. It is also evident that precipitation during critical periods is more important than the annual total, and that precipitation in the early spring months, although important to wheat production (*8*), had little relation to sorghum production.

Evaporation and relative humidity also had high correlations for July

TABLE 11.—*Correlation of climatic factors with milo-grain yields and kafir-grain and stover yields, Woodward, Okla., 1915–48*

Climatic factor	Coefficient of correlation with—		
	Milo grain	Kafir	
		Grain	Stover
Precipitation:			
June	+0. 097	+0. 048	−0. 140
July	+. 654	+. 583	+. 405
August	+. 622	+. 539	+. 472
July and August	+. 846	+. 743	+. 585
October to March	+. 437	+. 322	−. 170
October to May	+. 266	+. 189	----------
April to May	−. 063	−. 085	----------
April to August	+. 554	+. 441	+. 096
May to August	+. 515	+. 431	+. 108
June to August	+. 511	+. 598	+. 354
Annual	+. 287	+. 348	+. 064
Evaporation:			
July	−. 514	−. 555	−. 151
August	−. 709	−. 727	−. 640
July and August	−. 753	−. 788	−. 499
Relative humidity:			
June	+. 311	+. 354	−. 052
July	+. 612	+. 660	+. 269
August	+. 774	+. 779	+. 607
July and August	+. 780	+. 807	+. 502
Saturation deficit:			
July and August	−. 773	−. 823	−. 472
L. S. D. at—			
5-percent level	0. 328	0. 328	0. 328
1-percent level	. 417	. 417	. 417

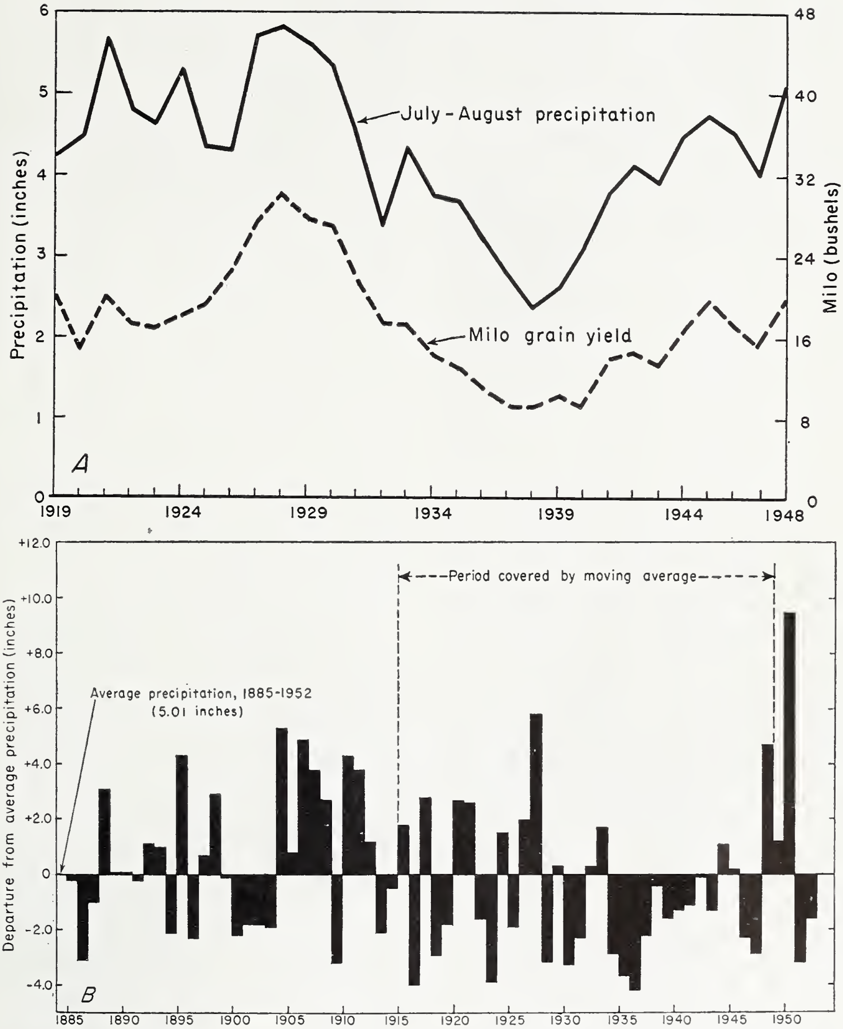

FIGURE 9.—*A*, Relationship between 5-year moving average of grain yield of continuously cropped milo and July–August precipitation, 1915–48; *B*, departure of July–August precipitation from longtime average, 1885–1952. Woodward, Okla.

and August, the highest being those for the 2 months combined. An important difference between precipitation and the other 2 factors is that the correlation of precipitation with yield is higher for July than for August, while the reverse is true for the other factors. These other factors have little residual effect from month to month. However, July precipitation, or part of it, may be carried over to August as soil moisture. This reduces the dependence of the crop on August precipitation (see p. 26).

Relative humidity and saturation deficit are complementary to a great extent; that is, relative humidity is a measure of the percentage of saturation of the air, while saturation deficit is a measure of the quantity of vapor by which the air lacks being saturated. They are not entirely complementary, however; saturation deficit is determined by quantitative measurement, and a given saturation deficit requires a given quantity of water to reach saturation. This is not true of relative humidity because temperature is a factor in its determination. Air with a given relative humidity holds less water and requires less water to become saturated when the temperature is low than when it is high. In this study, it was thought at one time that saturation deficit might be a better criterion of the yield than relative humidity, but it was found to have no advantage in this respect.

Results with kafir show that correlations for grain during the critical months of July and August are higher than those for stover (table 11). It seems likely that this is because adverse or favorable conditions may affect grain yields after stover has had most of its growth.

A few correlations with climatic factors were also made with forage sorghum or sorgo and with broomcorn brush. The correlations for sorgo, where all of the crop was harvested, were approximately the same as for kafir stover. Those for broomcorn brush were similar to those for milo and kafir grain.

The positive correlations between yield and July–August precipitation, and between yield and July–August relative humidity, are essentially of the same magnitude as the negative correlations for the same months between yield and evaporation, and yield and saturation deficit. (See table 11.)

These results apply especially to such conditions as those at Woodward and cannot be applied indiscriminately. At Dalhart, Texas, for example, the precipitation occurring between the harvest of one sorghum crop and the planting of the next is more than 4 inches lower than at Woodward, Okla. The capacity of the soil to hold water, however, is greater at Dalhart. How this places greater emphasis on water storage and less on current conditions is brought out by comparative correlations (table 12). At Dalhart precipitation before the crop was planted was fully as important as precipitation during growth (*10*). At Woodward the precipitation during July and August was of utmost importance. This does not mean that earlier precipitation was ineffective. It means that differences in early moisture storage were not large, and also that the quantities of water that could be stored before July were not great enough to offset deficiencies in July and August precipitation.

Soil-Moisture Studies With Milo

The soil-moisture work with sorghums was confined chiefly to a thorough study of 4 plots of milo—A, B, C, and D—located in the continuous-cropping group at the north end of series I (fig. 3). These consisted of a spring-plowed plot, a fall-plowed plot, and 2 plots alternately cropped and fallowed. In addition, moisture determinations were made in field B at different distances from the rows of wide-spaced milo.

The determinations were made to a depth of 6 feet at planting time and harvest, and at intervals between those times. During the period from late July through September, determinations were usually made at weekly intervals. Only the results for the first 4 feet of soil are discussed herein. Milo used water from depths greater than 4 feet; but changes below that depth were small, and the experimental error due to soil variability was so great that inclusion of the fifth- and

TABLE 12.—*Comparison of correlations between precipitation for selected periods and grain yields of milo and kafir, Dalhart, Tex., and Woodward, Okla.*

Precipitation period	Coefficient of correlation with—			
	Dalhart[1]		Woodward[2]	
	Milo	Kafir	Milo	Kafir
October to May	+0. 681	+0. 636	+0. 266	+0. 189
April to May	+. 614	+. 542	−. 063	−. 085
May to August	+. 729	+. 655	+. 515	+. 431
July to August	+. 479	+. 470	+. 846	+. 743
L. S. D. at—				
5-percent level	0. 355	0. 355	0. 328	0. 328
1-percent level	. 456	. 456	. 417	. 417

[1] Average yields of continuously cropped plots, 1909–38.
[2] Average yields of continuously cropped plots, 1915–48.

sixth-foot sections would provide little additional information.

Soil-moisture data are not discussed in full detail; the discussion is limited to a few of the more important points brought out in the studies.

Definitions

A few general terms used to simplify the discussion are:

Minimum point.—The amount of water left in the soil after the milo crop has used all the water readily available. Crops in the field reduce the water content of the soil rapidly to a certain point; then water reduction ceases or nearly ceases. The minimum point was calculated for each plot and foot-section from determinations made when the crop needed water but was not able to reduce the soil water content further.

Available water.—Water which is in excess of the minimum point and which represents the portion of soil water that is readily available to crops.

Inches of water.—Moisture determined as percentages and calculated as inches of water, to indicate the quantities involved.

Available water at planting time.—The quantity of water available at planting time, usually about mid-June.

Average available moisture in August.—The average of weekly determinations (usually 4 in number), made during August. (By August, sorghum roots are well distributed through the first 4 feet of soil.)

Available Water at Planting Time

The average quantities of available water in the top 4 feet of soil at planting time, for the 4 tillage methods, were:

Tillage method:	Available water *Inches*
Spring plowing	3. 97
Fall plowing	4. 25
Fallowed land	4. 33
Land being fallowed	4. 11

The average data show why there was so little response to different methods of tillage or to fallowing. Continuously cropped land contained almost as much water at planting time as land that had been fallowed for a year. Data in a few individual years (tables 24 and 29, Appendix) show that in years when there was a material difference between plots, the plot with the highest water content at planting time generally produced the highest yields. The only notable exception was in 1933 when the soil-moisture supply was low at planting time, especially on the spring-plowed plot. The relatively loose condition of the soil on this plot permitted it to absorb a greater portion of later rains than the firmer, fall-plowed or fallowed plots. Sizable differences in water content occurred so seldom, however, that the average correlations were low. Correlations between yield and water at planting time, while positive, were either a little above or a little below the figure required for significance at the 5-percent level.

The fact that a year of fallow is not effective in storing additional water is brought out by the comparison between the plot that has been fallowed and the plot being fallowed. The difference in moisture content was only 0.22 inch, a poor return for a year of fallowing.

Available Water in August

It has long been observed that an uninterrupted growth during the period of rapid growth (July and August) is necessary for high yields of grain sorghums. Soil-moisture data showed that in many years the soil moisture was depleted or nearly depleted during August. When this occurred the potential yield was reduced in proportion to the severity of the water shortage. The data were examined to find to what extent yields depended on the August water content of the soil. The correlation between the August available-moisture content and the yield of the 2 continuously cropped plots was 0.798. This correlation is almost as high as that for the July-August precipitation. Correlations for the fallowed plots, though lower, were still highly significant.

The relationship between yield and the available-water content at planting time and in August are illustrated (fig. 10). This figure shows the reason for low correlation between water content at planting time and yield. In all but a few years, the available water content at planting time was at a fairly uniform high level. In only 2 years, 1933 and 1939, was the water content low at planting time. In 2 other years, 1921 and 1941, the water content was considerably above the average; in these 2 years, the actual quantity that the crop could use was probably no different from that in many other years, but the sample was taken so close to a period of heavy precipitation that the soil temporarily held water that was eventually drained away or otherwise lost.

The conclusion is that correlation between yield and available water in August is high, and that an abundant supply of available moisture during this critical period assures above-average yields of milo.

Field Water Use by Milo During Period of Rapid Growth

The period of rapid growth of milo extends from about mid-July to early September. Water loss from the soil during this period was determined by selecting data for rainless periods of several weeks' duration. For this study, rainless periods were selected so as to exclude loss from runoff and to reduce the loss caused by direct evaporation from the soil. Periods of several weeks' duration were chosen to reduce the daily experimental error in sampling. Spreading the experimental error between the

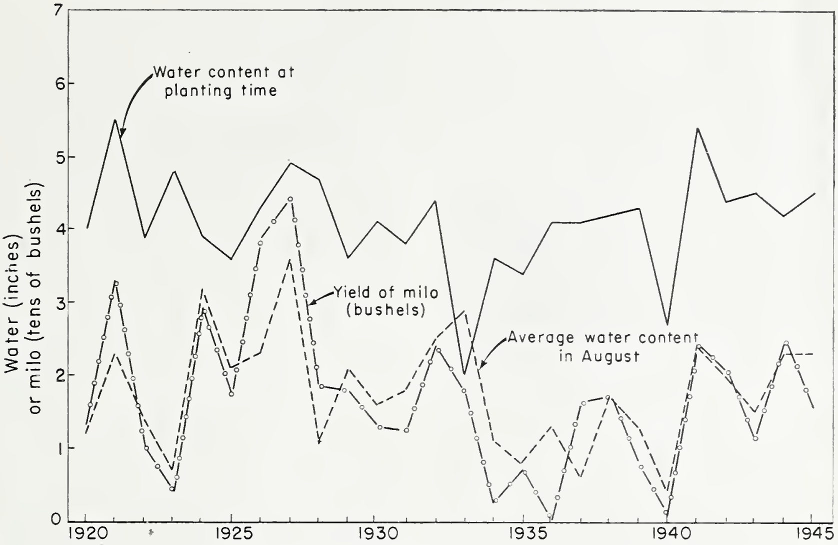

FIGURE 10.—Available water in the soil at planting time and in August, and yield of milo. (Data are the average of continuously cropped plots A and B, Woodward, Okla., 1920–45.)

samplings over a considerable number of days reduced that applicable to each day to a reasonably low figure. Even with these precautions, the data were somewhat variable, but they were consistent enough to permit conclusions to be drawn.

During this period of rapid growth, the average rate of moisture loss from the soil when well supplied with water was from 0.12 to 0.15 inch per day. This included both the loss through the crop and loss by direct evaporation from the soil. Use of less than 0.10 inch per day meant that the crop was obtaining less water than it needed. A rate of much less than 0.10 inch per day was invariably accompanied by drought injury and sharply reduced yields.

It was further observed that moisture losses ran higher when the soil was plentifully supplied with water than when the supply was less abundant. How much of this was due to increased loss through direct evaporation from the soil is not known.

The rate of use during the period of rapid growth explains why adequate July–August rainfall is essential to good yields. The soil does not hold enough available water to carry the crop without injury through the period from the time rapid growth commences until heading takes place. Nor is the normal rainfall for this period high enough to supply the needs of the crop. The average quantity of stored moisture at the beginning of this period, plus the normal rainfall, is sufficient to produce medium but not maximum yields. This explains why July–August rainfall, above or below the average, is a definite factor in determining final yields.

Use of Water by Milo in Wide-Spaced Rows

In the early thirties, growing sorghums in wide-spaced rows was strongly advocated. It was argued that this method of production would provide feed and, if most of the stalks were left standing, afford protection against wind erosion. At the same time, it would leave a soil-moisture condition comparable to that left by summer fallow.

When rotations of wheat and wide-spaced milo (rows 16½ feet apart) were started in field B at Woodward, moisture determinations at distances of 2, 4, 6, and 8 feet from the row were begun both on Wheatland, a combine-type milo, and on Dwarf Yellow, one of the more productive, larger growing types. The determinations were carried on for only a few years, as they required a great deal of labor. Furthermore, it was felt that the data obtained during those few years provided satisfactory information on the area where the milo affected the water content. Comparative results with the 2 types of milo are shown (fig. 11).

It is apparent that the water status in this experiment was not comparable to that resulting from fallow. Considerable water loss occurred at 2 and 4 feet from the row, and a slight amount at a distance of 6 feet. The loss at a distance of 8 feet was probably from causes other than root action. The extent of additional loss caused by milo roots at points closer to the row can be expressed by the difference between the water loss at that point and the loss at a distance of 8 feet.

Dwarf Yellow milo removed more moisture than Wheatland. When Dwarf Yellow was planted in rows 16½ feet apart, the milo yield averaged 10.5 bushels per acre, and that of wheat following milo averaged 14 bushels per acre. On the other hand, when Wheatland was planted in rows so spaced, the yield of milo averaged 6.8 bushels per acre, and that of wheat following milo averaged 17.3 bushels per acre. The greater feeding range of Dwarf Yellow milo increased its yield and reduced the yield of wheat that followed it.

Water Loss From Land Being Fallowed

The reduction in water content 8 feet from the row in the widely spaced sorghums (fig. 11) illustrates the change that would have taken place on this group of plots in these years if they had been fallowed. Longer results from field A illustrate a similar condition. As shown in table 29, the planting-time mois-

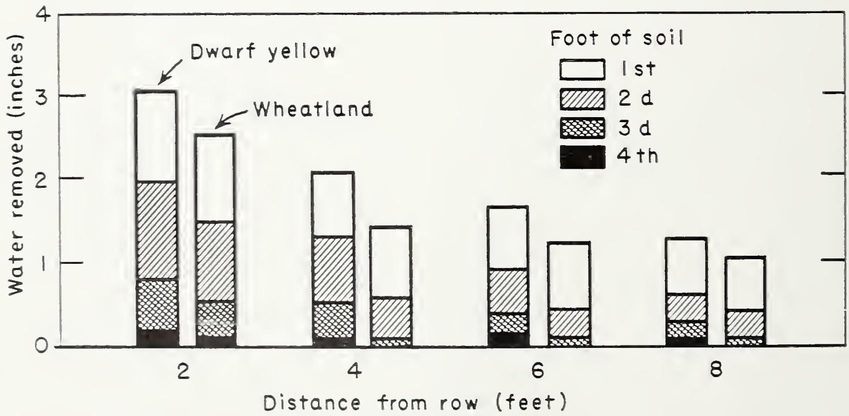

FIGURE 11.—Average water reduction at various soil levels between planting time and August by 2 varieties of milo in wide-spaced rows (16½ feet apart) at distances of 2, 4, 6, and 8 feet from the row, Woodward, Okla., 1936, 1937, and 1939.

ture content in the plot to be fallowed was only a little below that present after a year of fallow; consequently, there was no accumulation during the summer months. The first and, to a lesser extent, the second foot of soil lost water during dry, hot periods, presumably by evaporation. On an average, the water content on fallowed land was lower at the end of the summer than at planting time. However, this loss was easily replenished by precipitation in the fall, winter, and spring. The data illustrate that it is only in exceptional cases that any build-up occurs in summer. Fallowing this type of land that is already nearly full of water merely wastes precipitation. If changes occurred in depths of more than 2 feet, they were so small that they were obscured by the experimental error in sampling.

Corn

When the work at Woodward was started, corn was considered an important crop, and it was included in a number of rotations. It soon became evident, however, that production was low and uncertain compared with that of sorghums. When the schedule was revised in 1918, only the continuously cropped corn plots and a few in rotations were retained.

Under such climatic conditions as those at Woodward, corn has been subject to complete grain failure because the ears have not formed. This deficient development frequently results from hot, dry weather at tasseling time. The stover growth of corn, while much lower than that of kafir, has been reasonably good in most years. The average yields (table 13) included 9 years of complete grain failure and 4 additional years in which the average yield was considerably less than 5 bushels per acre. Detailed results (see table 30, Appendix) show 5 successive years of complete grain failure during the hot, dry years of the early thirties. Detailed stover yields are also given. (See table 31, Appendix.)

TABLE 13.—*Average yields of corn grain and stover in rotation and tillage plots, fields A and B, Woodward, Okla., 1915–48*

Previous crop and treatment	Period	Average yields per acre of—	
		Grain	Stover
Field A:			
Corn:		*Bushels*	*Pounds*
Spring-plowed	1915–48	9. 8	1, 727
Fall-plowed	1915–48	9. 4	1, 769
Fall-plowed and subsoiled	1915–48	9. 4	1, 754
Listed at planting	1915–48	5. 5	1, 102
Spring-cultivated, lister-planted	1915–48	4. 2	1, 003
Fallow (alternate corn and fallow)	1915–48	9. 0	1, 874
Kafir:			
Spring-plowed (corn in double-width rows)	1915–48	9. 4	1, 578
Spring-plowed (corn in regular-width rows)	1919–48	8. 6	1, 603
Wheat:			
Fall-plowed (corn in double-width rows)	1915–48	7. 7	1, 569
Fall-plowed (corn in regular-width rows)	1919–48	9. 4	2, 016
Field B:			
Wheat, fall-plowed	1933–48	9. 3	2, 149

Attempts were made to improve results with corn by finding adapted varieties and by adjusting dates and methods of planting, but none of these efforts was especially effective. No variety proved superior to others in setting ears under severe conditions. Date-of-planting tests conducted during the early years showed that corn, in contrast to sorghums, did best when planted about the middle of April.

Results from tillage variables showed that the only method materially different from the others was listing, which resulted in significantly lower yields. Cultivation in advance of lister planting was of no benefit, because the planting was done before weeds started to develop.

Summer fallow did not increase the grain yield of corn or the reliability of production. Corn on fallowed land failed to produce grain each year in which other methods failed. Stover yields were increased slightly by summer fallow.

Corn in double-width (88-inch) rows produced grain in 1916 when all other methods failed, but this did not occur again in the other 8 years of complete grain failure. Although this method of planting was expected to result in more reliable grain production through delayed moisture exhaustion in the larger areas between rows, it had little effect on reliability of production or on total yield.

Corn was grown in manured and unmanured 3-year rotations from which all crops were harvested for feed. The results are shown (table 14). The relative stover yield of the manured plot increased gradually with time, but the grain yield did not.

Since temperatures seemed to be instrumental in determining corn production, correlations covering different periods of time were made between yields and excess temperatures. The best correlation determined during these studies was for the degree-days above 90° F. for a 6-week period extending from 9 weeks before harvest to 3 weeks before harvest. This included, on the average, the period June 10 to July 22, although the actual dates varied in different years. The correlation for the degree-days above 90° was much higher than for the degree-days above 95° or above 100°.

The actual correlations between yields and degree-days above 90° F. for the period mentioned were −0.888 for grain and −0.462 for

TABLE 14.—*Average grain and stover yields of corn, by periods, in manured and unmanured rotations, Woodward, Okla., 1915–37*

Period	Manured rotation		Unmanured rotation	
	Grain	Stover	Grain	Stover
	Bushels	*Pounds*	*Bushels*	*Pounds*
1915–19	3. 4	1, 942	4. 5	2, 216
1920–25	8. 3	1, 610	9. 8	1, 600
1926–31	10. 7	2, 190	16. 3	1, 905
1932–37	2. 2	1, 555	1. 7	1, 298
Average for all years, 1915–37	6. 2	1, 818	8. 2	1, 735

total pounds of grain and stover. Correlations between precipitation and yields for the same period were +0.862 for grain and +0.567 for total pounds of grain and stover.

Even though corn provides a relatively good seedbed for winter wheat, total grain yields of wheat and corn in 2-year rotations were lower than those of similar rotations of grain sorghums and wheat.

Cowpeas

Cowpeas for hay were grown in twelve 2- or 3-year rotations in field A, and in a single rotation in field B. The crop proved unresponsive to differences in preceding crops and cultural methods. It was much less affected by differences in location than were other crops. Average yields are shown (table 15) and detailed yields (table 32, Appendix). The only substantial difference shown by individual plot studies was the increase in yield of cowpeas following wheat.

Cowpeas have been fairly reliable, and the crop has never failed completely, although hay yields have been low in some years. They dry rather slowly in wet seasons and sometimes shed a portion of their leaves in dry seasons. Obtaining a good quality of cured hay has been difficult. Crops following cowpeas have been about equal in yield to crops following corn. There is no evidence that harvesting cowpeas for hay has reduced losses of soil nitrogen and carbon below those incurred when growing nonleguminous row crops. Cowpeas leave the soil in a condition susceptible to wind erosion; and soil movement is likely to occur in winter and spring unless the land is planted to fall-sown grain that is able to provide a protective cover, or is roughened by tillage.

The place of cowpeas in a farming system is fixed primarily by their value as a crop. The need for a leguminous annual hay crop has not been great enough to encourage widespread production.

Variety tests that included both hay and seed production and date-of-planting tests were conducted for a number of years. No variety produced a good seed crop regularly enough to make seed production attractive. Several varieties, including Iron, Early Red, Groit, and Brabham, produced approximately equal hay yields. Date-of-planting tests showed wide and erratic differences between plantings on different dates. On the average, plantings

TABLE 15.—*Average yields of cowpea hay in rotation experiments, field A, Woodward, Okla., 1919–48*

Preceding crop and treatment	Number of plots	Average yields of hay per acre
		Pounds
Kafir:		
Spring-plowed	6	1, 948
Fall-plowed	1	1, 970
Milo:		
Spring-plowed	2	2, 085
Fall-plowed	1	2, 088
Wheat, fall-plowed	2	2, 225
Average for all plots	----------	2, 031

made the first part of June were more productive than those made earlier or later.

Cotton

When Oklahoma was settled, it was generally regarded as a Southern State and therefore a cotton-growing State. Considerable cotton was planted in this area for a few years following settlement, although most of the farmers who located in northwestern Oklahoma were unaccustomed to growing the crop. The rise in wheat prices at the time of World War I led to the abandonment of cotton growing. About 20 years after that war, cotton temporarily became an important cash crop as far north as Woodward.

Greater net returns from competing crops requiring less hand labor, rather than low cotton yields, has generally been the cause of reduced cotton acreages, although cotton on farms in the area has not regularly been planted early enough to obtain best yields. Cotton can be grown successfully in northwestern Oklahoma when prices received for it compare favorably with those paid for other crops.

Exploratory experimental work on cotton was done at this station during the period 1914–19. This consisted mostly of rotation experiments and small variety tests. Most of the plantings were late (June 1 or later), yields were low, and changes in varieties were frequent; therefore the information gained was limited. A few years later, more extensive variety and date-of-planting experiments were conducted.

After the discovery in 1925 that good stands of early-planted cotton could be obtained by treating the seed with copper carbonate, considerable progress was made. Before 1925, extremely early plantings had seemed impractical because of poor germination and also because of the excessively heavy rates of seeding required to obtain satisfactory stands. It was found that the use of copper carbonate at the rate of 4 to 5 ounces per bushel of seed often resulted in obtaining good stands as early as April 20. Late plantings did not benefit greatly from seed treatment, and yields from these plantings were usually low because of the shortened growing season.

It has been found that good stands are more easily obtained from surface planting or extremely shallow listing than from deep listing. Cotton grows better on moderately fine-textured land, such as would be chosen for seeding wheat, than on light sandy land.

During the period 1926–34, over 35 varieties or selections were grown for periods ranging from 1 to 9 years. In general, it was found that plantings made between April 20 and May 20 gave the highest yields, although stands from April 20 plantings, even with treated seed, were not so good as those from later ones. Yields fell off rapidly from plantings made after May 20. Average yields of 3 representative varieties for the period 1926–34 are shown (table 16). These results indicate that in this area cotton should be planted no later than May 20.

Another phase of experiments with cotton consisted of a tenth-acre plot in rotation with kafir in field A, and a similar plot in rotation with wheat in field B, beginning in 1934 and 1932, respectively. These plantings were always made early in May. Yields in field A during this period ranged from 0 to 1,080 pounds of seed cotton with a 14-year average of 524 pounds. Yields in field B ranged from 0 to 1,460 pounds of seed cotton with a 16-year average of 548 pounds.

TABLE 16.—*Average yields in pounds of 3 varieties of cotton in a date-of-planting test, Woodward, Okla., 1926–34*

Variety	Average yield per acre of seed cotton, when planted on—					
	April 20	May 1	May 10	May 20	June 1	June 10[1]
Acala 5–37	288	288	290	289	191	172
Oklahoma Triumph 44	294	326	313	317	210	173
Westex	329	332	322	310	221	169
Average	304	315	308	305	207	171

[1] This date of planting was used 1926–31 only. The yields in this column are adjusted to the longer period, 1926–34.

Sweetclover

Two rotations that included sweetclover were started on field A in 1914. Sweetclover seeded on fallowed land failed in most years and produced only a low yield in others; those rotations were discontinued in 1919. Fallow provided a soil well supplied with moisture, but its susceptibility to soil movement when the plants were small may have contributed to the failures.

Experiments designed to find a better way to grow sweetclover were carried on in a few of the years between the time the rotations in field A were discontinued and the time work was started in field B. These experiments showed that a crop-residue cover helped greatly in obtaining good stands. The stubble of drill-seeded sorghums that had been harvested for hay was especially good because it provided a firm seedbed relatively free from weeds and, at the same time, provided enough residue to protect the young plants. Date-of-seeding results showed that seedings in most parts of the year were successful provided moisture conditions were favorable. Obtaining an initial stand, however, was only part of the problem, as promising initial stands sometimes died out during hot, dry weather.

Two rotations were started in field B in 1933, which was the beginning of a hot, dry period. One of these was a 3-year rotation of wheat, wheat, sweetclover, with the sweetclover fall-seeded in one-wayed wheat stubble. During the 9 years that this rotation was in operation, only one crop of sweetclover hay was harvested. Good initial stands were lost or were unproductive because of the hot, dry weather and competition from volunteer wheat and weeds.

A second rotation consisting of wheat, wheat, sorgo hay, and 2 years of sweetclover was also started on field B in 1933. The sweetclover was spring-sown on sorgo-hay stubble. This was a much better way of growing sweetclover, but even this method failed during hot, dry years. During the period 1934–40, only 2 crops of second-year and 1 of first-year clover were obtained. The average hay yield of the second-year crop was only 190 pounds to the acre. Conditions were much more favorable in 1941–48, and during this period there was only 1 complete failure of second-year and 2 of first-year sweetclover. The average yields during this 8-year period were

690 pounds of first-year hay and 2,368 pounds of second-year hay. During the whole 15-year period, the average yield of hay from second-year sweetclover was 1,349 pounds. This contrasted unfavorably with the yield of sorgo hay in the same rotation which failed only once in the 15 years (1934–48) and produced an average hay yield of 3,713 pounds.

In each of the two rotations in field B, the yield of wheat after wheat was higher than that of wheat after sweetclover.

Green-Manure Crops

Four crops were used as green manures in rotations in the two fields. Winter rye and cowpeas were used in field A. As discussed earlier (p. 24), these crops were approximately equal as green manure. They produced moderate increases in the yield of kafir immediately following them and had a slight residual effect on wheat, but they did not develop any cumulative improvement in kafir yields over a rotation without amendments. Judged on the basis of results of the 34-year trial period, their use was a continued economic loss. After plot work was discontinued, the land occupied by these rotations was seeded uniformly to wheat, and there appears to have been a residual effect from the amendments.

Rye was used as a green manure following wheat and preceding kafir, and also following kafir and preceding wheat. The rye planted on kafir land developed slowly, and it produced only about half as much green matter to be turned under as was produced where rye followed wheat.

Hairy vetch, Austrian winter peas, and cowpeas were grown both as green manures and as harvested crops in 2-year rotations with wheat. Hairy vetch and Austrian peas afford some advantages as green-manure crops. They are fall-seeded and are plowed under relatively early in the spring. Before wheat-seeding time in the fall, the soil is able to accumulate quantities of water comparable to those quantities conserved in fallow. In spite of this, yields of wheat following these crops were no higher than on fallowed land during the 16 years in which they were under trial. Wheat on land where legumes had been plowed under made a much better early-fall growth than on fallowed land, but this was not reflected in the final grain yield. Comparison between the 3 legumes plowed under with the same legumes harvested for hay showed no increase in yield for plowing under for any crop except cowpeas. Thus, plowing under resulted in an average annual loss of hay ranging from 2,160 pounds for vetch to 1,380 pounds for Austrian peas. Green-manure crops have not been profitable at Woodward, and there is no evidence that their use has resulted in soil improvement that would compensate for the expense incurred in their production.

Soybeans

A large number of varieties and strains of soybeans were tested over a period of about 6 years in an attempt to find one adapted to local conditions. None of the strains tested compared favorably in hay production with the better varieties of cowpeas. Nearly all the plants shed their leaves when conditions were severe. A further disadvantage, as far as production on the station was concerned, was that they had to be protected by a rabbit-proof fence.

Mung and Tepary Beans

Mung beans were grown for several years as a hay crop. Yields of the dwarf variety were somewhat higher than those of cowpeas, but the quality of the hay was generally poorer.

Tepary beans were grown in only a few of the hot, dry years of the early thirties. They proved to be reasonably well adapted to such conditions. They retained their leaves better than other annual legumes and produced a good quality of hay. Seed production was much higher than that of cowpeas or soybeans, but the peculiar flavor of these beans makes them unacceptable as food for most people. They were not tested in more favorable years, as station finances made it necessary to discontinue all miscellaneous variety testing after 1935.

Peanuts

A single plot of peanuts was grown in rotation with kafir. The yields of nuts ranged from complete failure in several years to a maximum of 1,710 pounds in 1920. The average yield was 599 pounds of nuts and 2,214 pounds of hay. (See table 8.) The hay yields approximately equaled that of other annual legumes.

Annual Hay Crops in Manured and Unmanured Rotations

Sudan grass, cowpeas, and winter rye were grown in that order in 3-year manured and unmanured rotations. All 3 crops were removed as hay. The relative average hay yields were 3,450 pounds for Sudan grass, 1,940 pounds for cowpeas, and 2,295 pounds for winter rye.

The increasing difference between the manured and unmanured rotations is shown in detail (table 33, Appendix). The removal of all crops each year made this group of rotations extremely soil-depleting. During the 23 years of the experiment, the hay production per acre from the manured rotations in comparison with that from the unmanured rotations increased slightly over 100 pounds for cowpeas, 200 pounds for winter rye, and 600 pounds for Sudan grass. The difference would have been still greater had not the period 1932–37 been one of relatively low production. The gradually increasing spread between the 2 rotations during the period they were in operation is shown (fig. 12).

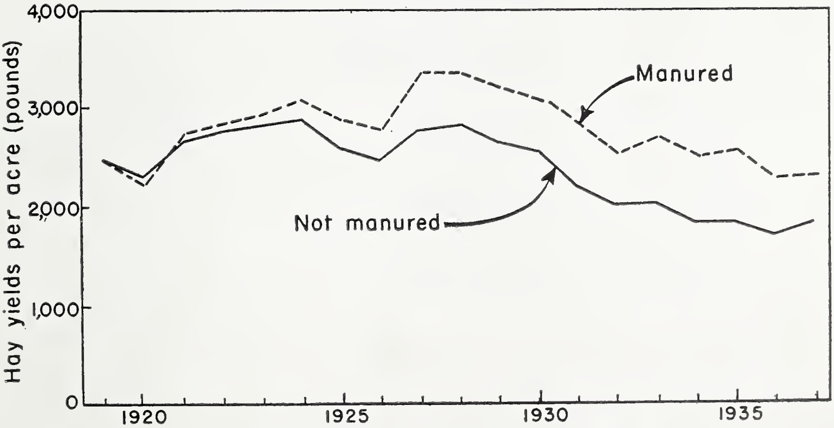

Figure 12.—Five-year moving averages of hay yields from a manured and an unmanured rotation. The yields are the combined average for cowpeas, winter rye, and Sudan grass.

Effects of Cropping Practices on Nitrogen and Carbon Content of Soil

When field A was placed under cultivation in 1914, a composite soil sample was taken to determine the nitrogen content of the first foot of soil. Individual plots were not analyzed separately. The 12 plots making up the composite sample are indicated by the letter N in figure 3. In 1947 determinations of nitrogen and carbon to depths of 0 to 6 inches and 6 to 12 inches were made on 29 individual plots to determine their fertility status. Detailed data, divided into general groups, are given (table 34, Appendix). Since the original determinations were not made for individual plots, there is no exact basis for determining to what extent the 1947 levels resulted from treatment and to what extent they resulted from original differences. There is enough general agreement, however, to permit drawing the following broad conclusions: (1) Alternate row crops and fallow reduced the nitrogen and carbon content of the soil to a lower level than continuous row crops. (2) Annual applications of about 2½ tons of manure to land continuously cropped to sorghums slightly reduced the loss of nitrogen and carbon. (3) Rotations of cowpeas and sorghums were fully as soil depleting as continuous sorghums. (4) The plowing under of 17 crops of cowpeas in 34 years did not result in maintaining nitrogen and carbon at levels materially higher than those on land where cowpeas had been harvested for hay.

The extent to which nitrogen levels decreased under years of cropping can be indicated roughly by comparing the 1947 levels with the original level of the field as a whole (fig. 13). No treatment contained more than half as much nitrogen in 1947 as virgin sod con-

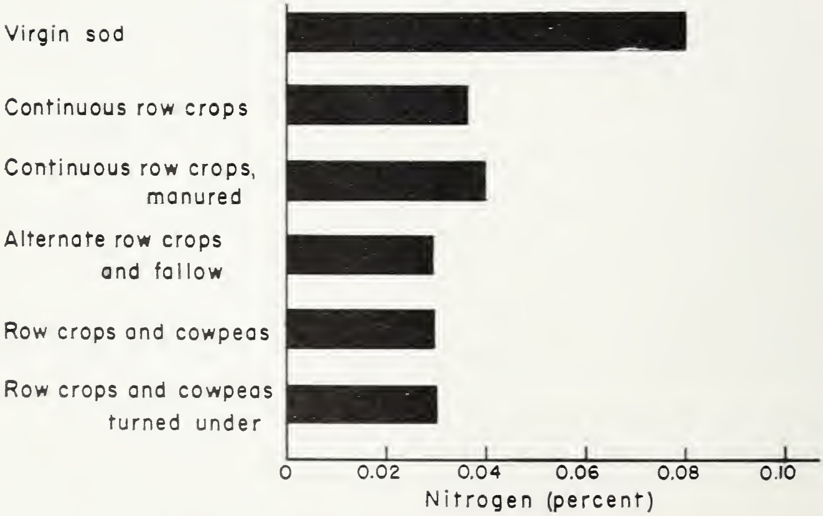

FIGURE 13.—Nitrogen levels of the first foot of soil in 1947, after approximately 34 years of cropping by different methods; and nitrogen level of virgin sod in 1914. Woodward, Okla.

tained in 1914. The loss under cultivation was reduced only slightly by soil-improvement practices. Comparisons between treatments are not exact. The general level of decline should be accepted as approximately correct, since 7 of the 12 plots used for making the original composite sample of virgin sod were included in the treatments. Summarized data are given (table 35, Appendix).

Fitting Sorghums and Wheat Into Farming Practice

Few practicable or profitable crop rotations have been developed for the area represented by Woodward. Next to wheat, the most important crops are the sorghums, and these are difficult to fit into rotations with wheat.

As shown earlier (p. 20), yields of sorghums following wheat were higher than yields following sorghums, and were substantially the same as on fallowed land. The relatively good yields of sorghums after wheat are explained by the fact that there is an 11- to 11½-month period for moisture storage between harvest of wheat in 1 year and planting of sorghums in the next. This permits moisture storage equivalent to that on fallowed land without involving the loss of a crop.

On the other hand, wheat seeded immediately after sorghums is at an extreme disadvantage. There is no appreciable interval between sorghum harvesttime and wheat-seeding time. In some years, unless wheat is seeded in the standing sorghum crop before harvest, its seeding is delayed beyond the optimum date. Even when wheat is seeded at its optimum date on land from which sorghum has been harvested, the seedbed is low in moisture and, frequently, in plant food. On the average, yields of wheat after sorghums have been only two-thirds as high as yields of wheat after wheat, and only half as high as yields of wheat on fallowed land. Growing wheat after sorghums has usually proved both undesirable and unprofitable. If all the land is to be in crop, more grain can be produced by growing sorghums after sorghums and wheat after wheat than by growing them in rotation.

The most practicable way of fitting sorghums and wheat into a rotation seems to be by introducing a year of fallow between the sorghums and the wheat. Such a rotation was successfully used in the production of wheat and sorghums on the Cereal Project at Woodward; and it was also found to be effective in other portions of the sorghum-and-wheat area, even where yields of sorghums after wheat were considerably lower than after fallow. A rotation of this type produces a little less grain than can be produced by growing both wheat and sorghums continuously, but the cost of production is likely to be enough lower to more than compensate for the difference in total yield.

Rotations of sorghums and wheat do not necessarily involve the same number of acres under each crop. Where sorgums are of secondary importance, the number of years of wheat can be increased, as in the following rotations:

Wheat, sorghum, fallow.
Wheat, wheat, sorghum, fallow.
Wheat, wheat, wheat, sorghum fallow.

The important feature in these rotations is that sorghum land is fallowed for wheat, to prevent the low yields and susceptibility to damage from soil blowing that can occur when wheat is sown on a moisture-deficient seedbed.

Rotations of this type provide for utilization of manure produced on the farm. The manure can be applied to the sorghum crop with immediate benefit to the stover if not to the grain yield. The residual effect of manure applications should eventually benefit the wheat crop. The year of fallow in the rotation provides better weed control than is attained when a crop is grown each year.

Summary

This circular reports the results of tillage and rotation experiments with sorghums and several other crops at the Southern Great Plains Field Station, Woodward, Okla., 1915–48. Next to wheat, grain and forage sorghums are the most important crops in the area represented by the station.

Tillage experiments with sorghums showed that results from fall plowing were slightly superior to those from spring plowing, but not enough higher to compensate for the greater soil-blowing hazard created. Plowing proved slightly superior to listing.

Results from tillage beginning in early spring were greatly superior to those from tillage beginning at or near the planting date.

Contour plantings of sorghums were more productive than noncontour operations, but the number of comparisons was not sufficient to establish specific differences.

Summer fallow was found to be ineffective as a means of materially increasing acre yields of crops discussed in this circular, or reducing the number of low yields.

Crop-sequence studies showed that yields of sorghums after wheat were higher than yields after row crops, and nearly equal to yields on fallowed land. Tillage of wheatland for sorghums was started shortly after harvest, and there was a period of approximately 11½ months between that time and planting time for sorghums.

All crops, including the sorghums, were less productive following sorghums than following small grains, corn, cowpeas, or cotton. The reduction in yield of winter wheat following sorghums was especially severe.

Barnyard-manure and green-manure crops increased the stover yield and, usually, the grain yield of the sorghum crop immediately following. There appeared to be no cumulative increase in yield in the recurring cycles of the rotations.

Kafir yields after cowpeas that had been harvested for hay were only a little lower than after cowpeas turned under for green manure.

Preliminary fertilizer experiments with sorghums showed a response to nitrogen and indicated possible deficiency in other fertility elements.

Studies of the effects of climatic factors on sorghum yields show high positive correlations between sorghum yields and July-August rainfall, and sorghum yields and July-August relative humidity. Correlations with grain yields were higher than those for stover. Strong negative correlations were shown for evaporation and for saturation deficit for the same months.

Soil-moisture determinations on milo showed why differential response to tillage practices was so limited in scope. All methods of tillage that controlled weeds resulted in soil nearly equally well filled with water at sorghum-planting time. On the average, sorghumland to be fallowed contained nearly as much water at planting time as it did a year later after a full year of fallow.

The quantity of available water held by the soil was not enough to carry the sorghum crop past the heading stage without material quantities of additional moisture furnished by rain; hence the dependence of yield on the July-August rainfall. Correlations between the available water present in August and the yield were approximately equal to those for the July-August precipitation and yield.

Sorghums in rows 16½ feet apart used moisture as far as 6 feet from the row. The reduction was considerably greater close to the row. The soil between wide-spaced sorghum rows did not approach summer-fallowed soil in moisture content at wheat-seeding time in the fall.

Corn yields of grain and stover were low in comparison with the yields of sorghums. No success was attained in increasing corn yields by improvements in planting time, planting methods, or varieties. Crops following corn yielded well, but not well enough to compensate for the low yield of the corn.

Cowpea yields proved to be fairly reliable. Most crops did well after cowpeas, and the cowpeas themselves were little affected by the crop they followed. The yield of hay was only about half as high as the yield of Sudan grass.

Cotton can be grown successfully in the Woodward area if seed treatment, time of planting, and variety receive sufficient attention. The extent to which it is grown depends on whether equal or better net returns can be obtained from competing crops requiring less labor.

Sweetclover, although productive in some years, was found to be poorly adapted for use in short rotations. Alfalfa was not grown in these rotation experiments.

In rotations where all crops were removed for hay, yields in manured rotations were progressively higher than in unmanured rotations.

Nitrogen determinations made in 1947 showed that land in row crops, or in alternate row crops and fallow, had lost more than half of its original nitrogen content during 35 years of cultivation. The loss was reduced only a little by annual light applications of manure, and none by plowing under a crop of cowpeas every other year.

Farmers growing both wheat and sorghums can fit them into a rotation practice by introducing a year of fallow between the sorghums and the wheat.

Literature Cited

(1) Anonymous.
1949. A STATISTICAL HANDBOOK OF OKLAHOMA AGRICULTURE. Okla. Agr. Expt. Sta. Misc. Pub. MP–14, 127 pp., illus.

(2) Blood, K. D., and Hill, M. L.
1941. WHEAT PRODUCTION IN OKLAHOMA, 1894–1938. Okla. Agr. Expt. Sta. Cir. 92, 51 pp., illus.

(3) Chaffin, W.
[1953.] SORGHUMS FOR GRAIN AND FORAGE. Okla. Agr. Ext. Serv. Cir. 478, 20 pp., illus.

(4) Chilcott, E. F.
1937. PREVENTING SOIL BLOWING ON THE SOUTHERN GREAT PLAINS. U. S. Dept. Agr. Farmers' Bul. 1771, 29 pp., illus.

(5) Davies, F. F., and Sieglinger, J. B.
1952. DWARF KAFIR 44–14 AND REDLAN. TWO NEW COMBINE-TYPE GRAIN SORGHUMS. Okla. Agr. Expt. Sta. Bul. B–384, 11 pp., illus.

(6) Kiltz, B. F., Sieglinger, J. B., Osborn, W. M., Barnes, B. F., and Finnell, H. H.
1933. SORGHUMS FOR GRAIN AND FORAGE. Okla. Agr. Expt. Sta. Bul. 210, 48 pp., illus.

(7) Leukel, R. W., Martin, J. H., and Lefebvre, C. L.
1951. SORGHUM DISEASES AND THEIR CONTROL. U. S. Dept. Agr. Farmers' Bul. 1959, 50 pp., illus. (Revised.)

(8) Locke, L. F., and Mathews, O. R.
1953. RELATION OF CULTURAL PRACTICES TO WINTER WHEAT PRODUCTION, SOUTHERN GREAT PLAINS FIELD STATION, WOODWARD, OKLA. U. S. Dept. Agr. Cir. 917, 54 pp., illus.

(9) Martin, J. H., Sieglinger, J. B., and others.
1929. SPACING AND DATE-OF-SEEDING EXPERIMENTS WITH GRAIN SORGHUMS. U. S. Dept. Agr. Tech. Bul. 131, 47 pp., illus.

(10) Mathews, O. R., and Barnes, B. F.
1940. DRY LAND CROPS AT THE DALHART (TEXAS) FIELD STATION. U. S. Dept. Agr. Cir. 564, 68 pp., illus.

(11) Murphy, H. F.
1925. CULTURAL METHODS FOR CORN AND GRAIN SORGHUMS ON OKLAHOMA SOILS. Okla. Agr. Expt. Sta. Bul. 150, 7 pp.

(12) Sieglinger, J. B.
1923. GRAIN-SORGHUM EXPERIMENTS AT THE WOODWARD FIELD STATION IN OKLAHOMA. U. S. Dept. Agr. Dept. Bul. 1175, 66 pp., illus.

(13) ———
1926. THE SPACING OF GRAIN SORGHUMS. Amer. Soc. Agron. Jour. 18: 525.

(14) ———
1928. BROOMCORN EXPERIMENTS AT THE UNITED STATES DRY LAND FIELD STATION, WOODWARD, OKLA. U. S. Dept. Agr. Tech. Bul. 51, 32 pp., illus.

(15) ———, and Martin, J. H.
1939. TILLERING ABILITY OF SORGHUM VARIETIES. Amer. Soc. Agron. Jour. 31: 475–488, illus.

(16) Vinall, H. N., Getty, R. E., and Cron, A. B.
1924. SORGHUM EXPERIMENTS ON THE GREAT PLAINS. U. S. Dept. Agr. Dept. Bul. 1260, 88 pp., illus.

Appendix

Table 17.—*Monthly and annual precipitation in inches, Southern Great Plains Field Station, Woodward, Okla., 1915–48*

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual total
1915	1. 17	3. 44	1. 45	6. 53	5. 29	2. 43	3. 14	3. 62	5. 74	2. 36	0. 55	0. 06	35. 78
1916	1. 50	. 03	. 82	1. 78	1. 70	10. 26	. 00	1. 02	2. 34	1. 71	. 75	. 60	22. 51
1917	. 20	. 20	. 10	1. 58	1. 03	1. 37	1. 13	6. 65	2. 72	. 05	. 67	. 01	15. 71
1918	1. 60	. 29	2. 09	2. 22	4. 00	1. 91	. 73	1. 35	1. 24	3. 35	1. 53	2. 92	23. 23
1919	. 06	1. 53	1. 94	4. 10	4. 29	2. 22	1. 35	1. 87	. 63	1. 85	2. 37	(1)	22. 21
1920	1. 03	. 07	. 61	1. 06	3. 40	1. 29	4. 69	3. 00	5. 01	2. 55	1. 32	1. 53	25. 56
1921	2. 22	. 61	1. 33	1. 80	1. 91	5. 78	2. 50	5. 11	2. 94	. 01	. 00	. 11	24. 32
1922	1. 02	. 96	5. 08	2. 97	3. 95	. 18	1. 07	2. 31	2. 83	. 74	1. 15	. 00	22. 26
1923	(1)	. 06	1. 86	2. 32	8. 11	4. 20	. 69	. 39	9. 33	11. 99	. 89	. 84	40. 68
1924	. 03	. 81	2. 96	3. 14	. 78	1. 46	3. 07	3. 40	3. 22	2. 29	1. 90	1. 48	24. 54
1925	. 14	. 12	. 40	3. 18	1. 34	2. 06	2. 34	. 79	2. 44	. 70	2. 04	. 46	16. 01
1926	. 54	. 11	1. 89	1. 70	2. 23	3. 51	5. 18	1. 79	3. 37	6. 09	1. 09	1. 34	28. 84
1927	. 41	. 68	1. 22	2. 20	. 52	4. 30	6. 89	3. 93	. 77	. 21	. 09	. 23	21. 45
1928	. 01	1. 63	. 97	1. 58	6. 69	3. 74	1. 42	. 35	. 81	4. 54	3. 78	1. 03	26. 55
1929	. 92	. 20	2. 04	. 77	3. 41	. 58	3. 15	2. 10	4. 45	1. 89	2. 83	. 12	22. 46
1930	. 56	. 02	. 18	2. 58	7. 78	2. 93	. 28	1. 42	1. 06	2. 56	1. 71	. 49	21. 57
1931	. 26	. 94	4. 31	2. 23	3. 44	2. 69	1. 16	1. 53	2. 86	1. 55	5. 73	. 53	27. 23
1932	1. 06	. 82	. 46	3. 36	2. 33	9. 21	. 34	4. 98	. 41	. 64	. 01	1. 25	24. 87
1933	. 07	. 52	. 48	2. 42	1. 25	. 10	1. 87	4. 78	1. 72	. 86	. 52	. 20	14. 79
1934	. 83	. 50	1. 71	2. 08	2. 25	4. 69	. 09	1. 97	2. 50	1. 07	1. 93	. 93	20. 55
1935	. 86	. 79	. 90	. 01	7. 17	1. 61	. 30	. 95	1. 56	2. 32	2. 29	. 35	19. 11
1936	. 46	. 09	(1)	. 60	5. 21	2. 37	. 23	. 54	3. 53	1. 68	. 02	. 86	15. 59
1937	. 66	. 38	1. 78	. 48	2. 37	1. 68	. 51	2. 28	3. 91	3. 65	. 03	. 40	18. 13
1938	. 03	2. 21	1. 86	4. 77	8. 33	4. 55	3. 10	1. 45	2. 12	. 20	. 49	. 19	29. 30
1939	2. 84	1. 01	1. 59	4. 38	1. 66	3. 97	2. 58	. 85	(1)	. 09	. 44	. 83	20. 24
1940	. 93	1. 58	. 18	2. 27	1. 46	1. 26	2. 54	1. 16	1. 84	. 69	3. 43	. 75	18. 09
1941	2. 17	2. 00	1. 57	3. 66	8. 46	5. 72	2. 00	1. 92	2. 84	9. 66	. 64	. 58	41. 22
1942	. 26	. 82	. 77	3. 54	2. 01	2. 92	1. 92	2. 93	3. 31	4. 56	. 07	1. 11	24. 22
1943	. 01	. 15	. 54	1. 31	4. 84	1. 83	2. 27	1. 39	. 81	1. 49	. 36	3. 52	18. 52
1944	1. 04	1. 22	1. 69	6. 83	1. 93	1. 38	4. 38	1. 73	1. 91	4. 01	1. 29	1. 79	29. 20
1945	1. 18	. 76	1. 17	3. 37	. 87	2. 15	1. 70	3. 45	4. 51	. 21	(1)	. 20	19. 57
1946	. 32	2. 25	1. 65	. 03	2. 44	1. 81	. 29	2. 41	6. 34	5. 55	2. 44	1. 31	26. 84
1947	. 51	. 06	2. 55	4. 48	6. 44	1. 72	1. 72	. 39	. 06	. 03	1. 38	1. 78	21. 12
1948	. 09	3. 39	1. 43	1. 48	. 93	4. 82	1. 54	8. 18	. 47	1. 73	1. 28	. 09	25. 43
Average	0. 74	0. 89	1. 46	2. 55	3. 52	3. 02	1. 95	2. 41	2. 64	2. 44	1. 32	0. 82	23. 76

[1] Trace.

Table 18.—*Monthly and seasonal evaporation in inches, Southern Great Plains Field Station, Woodward, Okla., 1915–48*

Year	April	May	June	July	August	September	Seasonal, April-September
1915	5. 98	6. 73	6. 64	10. 04	6. 52	5. 76	41. 67
1916	5. 93	10. 09	8. 25	10. 67	11. 11	7. 88	53. 93
1917	6. 79	6. 98	11. 54	11. 72	7. 59	5. 26	49. 88
1918	4. 97	9. 27	8. 67	10. 08	11. 00	5. 79	49. 78
1919	6. 00	5. 36	6. 37	10. 69	9. 31	7. 60	45. 33
1920	7. 70	6. 45	10. 41	9. 79	6. 87	7. 27	48. 49
1921	6. 92	8. 04	7. 28	9. 32	10. 29	8. 75	50. 60
1922	7. 92	8. 91	10. 59	11. 03	11. 53	7. 84	57. 82
1923	5. 50	6. 34	8. 42	10. 70	11. 64	6. 50	49. 10
1924	6. 32	6. 42	10. 49	9. 09	9. 49	7. 41	49. 22
1925	6. 85	7. 17	11. 78	9. 87	8. 71	6. 57	50. 95
1926	4. 77	7. 34	10. 38	9. 70	8. 61	6. 97	47. 77
1927	5. 60	8. 16	9. 25	9. 81	6. 32	6. 96	46. 10
1928	7. 32	7. 00	7. 06	9. 84	10. 02	9. 24	50. 48
1929	6. 64	5. 33	9. 83	10. 37	11. 03	7. 62	50. 82
1930	7. 05	7. 31	9. 96	12. 96	11. 71	8. 84	57. 83
1931	4. 64	6. 88	10. 66	10. 83	9. 08	10. 90	52. 99
1932	6. 63	8. 32	7. 62	12. 23	10. 71	6. 63	52. 14
1933	7. 74	8. 92	12. 90	11. 39	8. 05	8. 28	57. 28
1934	6. 25	8. 76	12. 14	15. 78	11. 64	7. 13	61. 70
1935	6. 39	5. 59	7. 90	12. 11	11. 05	7. 09	50. 13
1936	7. 28	6. 91	10. 96	13. 01	13. 19	5. 86	57. 21
1937	6. 62	8. 30	9. 29	13. 48	10. 83	7. 17	55. 69
1938	4. 12	5. 97	8. 19	9. 44	12. 20	7. 04	46. 96
1939	6. 39	7. 88	9. 48	11. 79	10. 71	10. 90	57. 15
1940	6. 46	8. 15	10. 28	13. 14	9. 62	8. 03	55. 68
1941	5. 51	6. 62	7. 13	8. 73	8. 24	6. 95	43. 18
1942	5. 32	9. 04	8. 45	11. 43	8. 51	6. 95	49. 70
1943	7. 11	6. 14	9. 89	9. 90	12. 03	7. 30	52. 37
1944	5. 02	7. 61	10. 40	9. 23	9. 93	7. 14	49. 33
1945	4. 30	7. 99	7. 58	9. 42	9. 61	8. 58	47. 48
1946	7. 17	7. 93	10. 69	12. 22	9. 12	6. 14	53. 27
1947	4. 31	6. 39	9. 22	10. 23	11. 34	9. 72	51. 22
1948	7. 71	8. 29	8. 88	10. 17	7. 55	7. 56	50. 16
Average	6. 21	7. 43	9. 37	10. 89	9. 86	7. 52	51. 28

TABLE 19.—*Annual and average dates and temperatures of spring and fall frosts and freezes, and number of days between specified spring and fall temperatures, Woodward, Okla., 1915–48* [1]

Year	Date and low temperature, spring						Date and low temperature, fall						Number of days between temperature of—		
	24° F. or lower		28° F. or lower		32° F. or lower		32° F. or lower		28° F. or lower		24° F. or lower		32° F.	28° F.	24° F.
		° *F.*		° *F.*		° *F.*		° *F.*		° *F.*		° *F.*			
1915	Mar. 25	24	Mar. 31	27	Apr. 3	32	Oct. 26	32	Nov. 12	27	Nov. 23	14	206	226	243
1916	Apr. 8	22	Apr. 8	22	Apr. 9	32	Oct. 18	31	Oct. 19	27	Nov. 11	24	192	194	217
1917	Mar. 26	18	Apr. 1	25	May 7	32	Oct. 11	28	Oct. 11	28	Oct. 22	20	157	193	210
1918	Mar. 9	23	Mar. 15	27	Apr. 9	30	Oct. 26	31	Nov. 18	28	Nov. 22	23	200	248	258
1919	Mar. 4	17	Mar. 6	25	Apr. 9	31	Oct. 10	32	Oct. 27	27	Nov. 11	15	184	235	252
1920	Apr. 4	24	Apr. 4	24	Apr. 12	31	Oct. 31	32	Nov. 9	28	Nov. 11	20	202	219	221
1921	Mar. 30	24	Apr. 9	26	Apr. 16	29	Nov. 8	23	Nov. 8	23	Nov. 8	23	206	213	223
1922	Mar. 10	20	Mar. 10	20	Apr. 17	32	Nov. 5	32	Nov. 12	28	Nov. 13	22	202	247	248
1923	Mar. 19	17	Mar. 30	26	Apr. 7	30	Oct. 29	29	Dec. 1	27	Dec. 4	24	205	246	260
1924	Mar. 30	23	Mar. 31	26	Mar. 31	26	Oct. 22	32	Nov. 6	27	Dec. 7	21	205	220	252
1925	Mar. 14	21	Mar. 14	21	Mar. 26	29	Oct. 18	28	Oct. 18	28	Oct. 27	19	206	218	227
1926	Apr. 2	23	Apr. 2	23	Apr. 14	30	Oct. 23	32	Nov. 1	26	Nov. 17	18	192	213	229
1927	Mar. 20	18	Mar. 23	27	Apr. 20	29	Nov. 1	31	Nov. 5	26	Nov. 11	24	195	227	236
1928	Apr. 13	22	Apr. 14	28	Apr. 14	28	Nov. 1	26	Nov. 1	26	Nov. 18	23	201	201	219
1929	Feb. 28	23	Mar. 8	25	Mar. 31	29	Oct. 30	29	Nov. 3	26	Nov. 14	22	213	240	259
1930	Mar. 28	22	Mar. 29	26	Mar. 29	26	Oct. 16	32	Oct. 30	28	Dec. 5	24	201	215	252
1931	Mar. 31	15	Apr. 4	28	Apr. 20	32	Oct. 30	25	Oct. 30	25	Nov. 21	23	193	209	235
1932	Mar. 21	23	Mar. 21	23	Apr. 10	31	Oct. 25	32	Nov. 4	27	Nov. 14	20	198	228	238
1933	Mar. 22	23	Apr. 14	28	Apr. 15	32	Nov. 4	29	Nov. 15	28	Dec. 5	21	203	215	258
1934	Mar. 18	19	Mar. 24	27	Mar. 30	29	Oct. 27	29	Nov. 29	25	Dec. 2	22	211	250	259
1935	Mar. 7	23	Mar. 7	23	Apr. 11	31	Oct. 31	28	Oct. 31	28	Nov. 10	24	203	238	248
1936	Apr. 6	22	Apr. 6	22	Apr. 21	29	Oct. 21	30	Oct. 25	26	Oct. 26	24	183	202	203
1937	Apr. 4	23	Apr. 8	27	Apr. 8	27	Nov. 13	30	Nov. 15	26	Nov. 16	19	219	221	226
1938	Apr. 8	22	Apr. 8	22	Apr. 8	22	Oct. 22	24	Oct. 22	24	Oct. 22	24	197	197	197
1939	Mar. 14	22	Mar. 17	27	Apr. 18	31	Oct. 27	31	Nov. 2	31	Nov. 2	13	192	230	233
1940	Apr. 11	22	Apr. 11	22	Apr. 12	32	Nov. 6	29	Nov. 10	18	Nov. 10	18	208	213	213
1941	Mar. 17	24	Mar 17	24	Mar. 27	32	Oct. 27	32	Nov. 5	28	Nov. 22	18	214	233	250
1942	Feb. 27	12	Mar. 31	26	Mar. 31	26	Oct. 25	30	Nov. 9	28	Nov. 22	23	208	223	268
1943	Mar. 21	20	Mar. 22	29	Apr. 19	32	Oct. 15	31	Oct. 26	25	Nov. 28	24	179	218	252
1944	Mar. 29	20	Mar. 30	26	Apr. 17	31	Nov. 15	31	Nov. 20	28	Nov. 26	23	212	235	242
1945	Apr. 4	21	Apr. 4	21	Apr. 15	32	Oct. 21	30	Nov. 8	24	Nov. 8	24	189	218	218
1946	Feb. 13	19	Mar. 9	28	Mar. 9	28	Nov. 9	29	Nov. 10	26	Dec. 1	23	245	246	291
1947	Mar. 15	20	Mar. 15	20	Apr. 13	32	Nov. 4	30	Nov. 6	24	Nov. 6	24	205	236	236
1948	Mar. 27	23	Mar. 27	23	Mar. 31	29	Oct. 16	32	Nov. 8	26	Nov. 28	18	199	226	246
Average	Mar. 23	21	Mar. 27	25	Apr. 9	30	Oct. 27	30	Nov. 5	26	Nov. 16	21	201	223	238

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[1] These data are from temperature readings taken by the Southern Great Plains Field Station, Woodward, Okla., except that temperatures for fall of 1915 are from local records of the U. S. Weather Bureau at Woodward.

TABLE 20.—*Relative humidity (percent), Southern Great Plains Field Station, Woodward, Okla., 1915–48*

Year	April	May	June	July	August	September	Average	Year	April	May	June	July	August	September	Average
1915	57.5	62.0	64.8	60.7	71.2	70.0	64.4	1933	38.2	45.3	32.0	45.5	57.1	52.1	45.0
1916	58.4	49.0	62.6	49.4	48.6	56.0	54.0	1934	44.5	47.3	42.8	29.8	37.8	56.5	43.1
1917	57.7	55.7	40.1	46.6	64.2	65.0	54.9	1935	40.6	64.3	56.6	40.4	45.0	51.2	49.7
1918	61.9	53.4	54.6	54.5	47.9	62.4	55.8	1936	33.8	59.7	41.2	33.9	31.8	66.5	44.5
1919	68.8	75.1	72.2	59.8	63.3	63.5	67.1	1937	38.2	48.4	52.4	39.2	44.0	53.5	46.0
1920	52.7	67.0	58.5	58.5	67.3	62.9	61.2	1938	61.3	65.3	58.7	54.6	43.2	47.1	55.0
1921	56.4	55.9	70.0	61.4	54.1	57.4	59.2	1939	51.6	52.2	53.7	41.7	46.5	34.9	46.8
1922	65.0	61.4	56.0	53.3	48.5	49.9	55.7	1940	52.4	49.7	46.4	43.9	50.2	53.2	49.3
1923	66.0	64.2	63.4	51.4	45.5	66.3	59.5	1941	58.8	69.6	64.9	55.7	57.3	62.3	61.4
1924	57.6	54.3	51.8	56.7	55.2	55.8	55.2	1942	66.0	57.4	64.3	51.3	63.9	60.5	60.6
1925	53.1	59.1	61.9	62.0	63.4	73.5	62.2	1943	50.3	70.2	56.8	54.8	42.9	53.5	54.8
1926	65.2	68.1	60.8	64.0	61.1	68.5	64.6	1944	65.8	62.3	55.8	58.9	52.6	56.8	58.7
1927	67.7	62.1	58.6	55.0	74.4	59.3	62.9	1945	67.3	56.4	61.4	56.8	55.3	54.4	58.6
1928	49.8	59.7	69.0	57.1	54.0	49.6	56.5	1946	46.6	52.3	52.5	40.5	54.8	66.6	52.2
1929	54.7	69.4	56.0	55.7	48.5	60.0	57.4	1947	61.6	63.3	53.1	50.6	44.5	41.9	52.5
1930	50.1	62.0	55.5	47.3	44.6	42.5	50.3	1948	38.5	50.7	52.7	54.5	59.5	59.6	52.6
1931	61.8	55.2	48.0	46.2	47.9	44.8	50.7								
1932	51.2	54.0	65.8	50.3	56.3	54.1	55.3	Average	55.0	58.9	56.3	51.2	53.0	56.8	55.2

TABLE 21.—*Annual and average yields in bushels of kafir grain in rotation and tillage experiments, field A, Woodward, Okla., 1915–48*

Previous crop and tillage treatment	Rotation or plot	Acre yields in—																
		1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931
Kafir:																		
Spring-plowed	C. C.,[1] A	40.2	5.2	19.3	6.7	18.7	34.0	24.6	9.4	14.0	27.1	11.7	42.3	29.3	25.0	27.3	15.0	18.3
Do	160					18.2	34.0	15.6	8.3	15.6	26.2	23.1	37.1	20.2	14.7	31.7	13.2	17.5
Fall-plowed	C. C.,[1] B	40.2	6.8	22.2	7.9	19.9	36.0	29.8	8.5	15.2	27.3	27.3	42.7	36.3	25.7	28.3	13.2	21.5
Do	C. C.,[1] B′[2]					23.7	16.3	29.8	10.8	15.6	33.1	27.5	42.9	37.7	30.2	28.5	14.2	23.8
Do	402					13.2	28.1	25.6	6.7	9.2	29.2	20.2	36.3	31.3	22.3	22.2	10.0	15.8
Fall-plowed, manured	H					15.7	37.3	28.3	12.5	14.4	27.1	26.3	43.2	45.2	33.0	29.8	15.0	22.2
Fall-plowed, subsoiled	C. C.,[1] E[3]	38.3	4.8	25.2	6.2	17.3	32.1	24.6	7.3	9.8	26.5	19.2	44.0	31.5	19.2	24.3	12.7	15.5
Listed	C. C.,[1] F	32.2	3.7	22.0	4.2	16.2	24.0	22.9	7.1	3.1	22.1	13.8	17.1	13.8	12.5	19.2	12.2	11.7
Disked and listed	C. C.,[1] G	28.3	5.5	22.0	2.9	15.9	27.3	23.5	8.8	8.1	25.8	22.1	19.2	17.7	14.2	20.0	14.0	13.3
Milo:																		
Spring-plowed	162					15.4	35.2	19.0	8.3	13.3	26.9	20.0	34.6	20.7	15.7	25.0	16.3	18.0
Do	165					19.7	21.9	25.0	7.9	11.9	21.2	21.7	39.8	35.5	20.7	29.2	17.7	21.3
Do	294					14.6	24.8	27.7	10.2	6.2	30.0	17.9	43.1	24.3	25.5	25.0	9.7	17.2
Fall-plowed	161					18.1	32.9	22.9	10.8	21.8	31.2	22.7	43.5	34.7	18.8	33.5	19.8	18.2
Cowpeas:																		
Spring-plowed	284					15.2	35.0	28.3	9.0	9.2	28.3	19.2	38.3	35.0	21.8	24.0	8.8	17.2
Do	285					15.9	28.1	42.1	12.1	9.4	28.7	20.4	47.1	27.2	24.0	22.5	18.0	19.3
Do	[2] 285′					25.0	36.7	24.3	7.3	11.2	25.0	14.8	37.9	29.8	17.5	21.7	10.2	13.2
Do	160					27.2	32.9	32.3	8.1	13.7	29.4	25.2	37.1	16.7	21.8	23.0	17.2	20.0
Do	169					33.1	39.4	37.5	14.4	18.7	30.0	27.9	54.6	38.2	32.7	28.0	17.3	25.0
Fall-plowed	163					28.8	35.8	39.6	14.4	20.0	34.2	35.8	53.5	43.0	32.7	31.3	23.0	24.3
Plowed under for green manure	286					19.8	41.0	32.2	4.6	13.0	27.3	21.9	33.1	42.7	16.0	22.5	4.7	18.5
Do	154					19.7	44.4	42.1	12.1	11.2	23.7	24.8	52.5	27.5	31.3	34.8	7.7	18.3
Corn:																		
Spring-plowed	282					21.4	27.7	33.5	10.6	11.0	28.5	20.0	46.0	30.0	22.7	26.5	16.8	18.8
Do	153					16.7	34.4	35.4	8.5	12.5	26.2	21.9	36.5	37.1	26.3	25.5	14.0	20.2
Winter wheat:																		
Fall-plowed	402					15.2	29.8	30.0	6.3	11.9	27.3	18.3	32.3	34.7	19.8	24.8	14.7	21.8
Do	264					22.9	27.5	38.8	9.6	11.4	29.4	22.9	42.9	42.3	27.3	28.2	11.0	22.7
Do	167					29.3	38.1	41.7	14.8	21.2	30.8	36.3	60.4	45.0	35.5	36.0	26.8	31.8
Peanuts:																		
Spring-plowed	283					23.9	25.4	40.6	11.0	13.7	29.6	20.4	49.8	42.2	24.3	29.3	17.5	23.0
Cotton:																		
Spring-plowed	290					20.7	28.5	33.3	12.3	11.9	33.1	18.3	50.0	42.2	25.5	26.8	19.0	21.5
Fallow:																		
Summer-tilled	C. C.,[1] C, D	37.8	8.7	31.1	7.3	20.8	33.5	27.9	9.2	12.5	25.6	22.3	49.8	36.0	25.5	25.7	17.3	20.8
Do	155					17.3	28.1	29.8	6.7	9.2	15.6	18.8	29.4	29.0	24.3	25.0	14.0	17.5
Do	168					28.1	41.5	34.4	10.2	17.3	32.3	24.2	53.8	38.5	25.7	29.3	22.3	20.2
Summer-tilled, manured	288					15.7	36.5	28.5	6.9	5.8	23.7	17.3	38.5	41.3	22.2	18.3	15.2	15.2
Do	156					26.0	47.3	42.1	14.0	13.1	37.5	34.2	58.3	50.2	37.3	29.8	14.8	22.5
Summer-tilled, kafir topdressed	289					15.5	37.1	27.5	7.3	9.2	22.9	19.4	31.7	35.5	17.3	21.5	10.8	18.2
Winter rye:																		
Plowed under for green manure	151					24.6	23.8	37.1	10.2	13.7	29.8	29.4	48.5	29.0	27.3	30.0	13.5	22.5
Do	152					28.7	34.4	40.2	13.3	22.3	32.2	31.0	46.7	51.0	31.8	34.3	19.2	21.8

Previous crop and tillage treatment	Rotation or plot	Acre yields in—																	
		1932	1933	1934	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	Average
Kafir:																			
Spring-plowed	C. C.,[1] A	25.0	28.2	0	6.5	0	21.7	24.2	14.7	0	31.8	31.0	15.7	22.3	24.0	24.0	5.5	31.7	19.8
Do	160	21.7	24.8	0	11.0	0	19.0	14.7	3.8	6.5	22.3	18.8	8.5	20.7	8.3	10.5	4.7	14.2	16.2
Fall-plowed	C. C.,[1] B	30.0	24.7	0	6.3	0	17.3	21.7	16.3	0	35.0	29.2	10.2	23.8	24.0	22.5	6.8	33.3	20.9
Do	C. C.,[1] B′[2]	24.8	25.2	0	3.3	0	18.2	22.5	13.2	0	39.8	32.3	12.7	23.0	22.5	22.7	15.2	39.0	21.6
Do	402	22.5	25.5	0	6.8	0	13.5	13.5	10.5	0	36.7	26.0	8.7	20.7	18.5	13.3	8.3	34.7	17.6
Fall-plowed, manured	H	23.2	24.3	0	4.0	0	14.2	21.8	16.5	0	40.5	34.0	9.7	23.3	20.5	29.8	9.8	43.5	22.2
Fall-plowed, subsoiled	C. C.,[1] E[3]	26.5	24.8	0	6.5	0	20.2	14.8	7.3	0	21.3	19.2	6.8	13.5	16.0	11.0	4.8	21.3	16.8
Listed	C. C.,[1] F	21.3	18.8	0	2.5	0	11.8	13.3	4.0	0	18.3	9.3	0	19.8	11.0	4.0	1.8	16.5	12.1
Disked and listed	C. C.,[1] G	22.3	21.5	0	5.5	0	17.5	15.8	6.7	5.7	17.3	27.5	7.3	18.3	13.8	8.2	2.7	17.3	14.6
Milo:																			
Spring-plowed	162	24.2	22.7	0	10.8	0	23.3	19.0	6.5	8.3	21.7	22.3	5.8	18.8	13.8	9.7	6.7	16.7	16.6
Do	165	24.3	33.0	0	3.3	0	20.8	23.3	13.0	0	31.5	23.5	9.8	18.5	18.8	17.8	13.3	26.0	19.0
Do	294	27.3	20.7	0	3.3	0	10.8	22.7	7.2	0	27.3	20.0	8.0	22.2	16.5	18.5	8.5	33.8	17.4
Fall-plowed	161	30.2	23.2	0	12.3	0	18.3	29.8	19.7	0	39.3	24.3	15.8	28.0	21.0	15.7	16.7	32.0	21.8
Cowpeas:																			
Spring-plowed	284	23.5	39.7	0	5.2	0	23.3	12.7	10.0	0	26.7	29.2	4.3	19.3	21.8	23.5	2.3	34.7	18.9
Do	285	24.3	33.2	0	3.5	0	18.2	23.5	12.7	0	31.0	29.7	8.2	23.0	25.5	20.8	13.5	33.3	20.5
Do	[2] 285′	17.5	30.0	0	7.2	0	22.3	10.5	5.8	0	18.8	22.5	4.0	14.0	20.5	24.3	3.2	19.0	16.5
Do	160	18.3	33.8	0	8.0	0	22.2	13.8	7.3	0	18.0	23.5	8.5	17.3	13.5	10.0	3.0	21.0	17.4
Do	169	26.8	33.5	0	6.0	0	17.3	30.0	13.8	2.2	30.7	28.0	21.8	29.2	24.0	23.5	11.0	31.3	24.2
Fall-plowed	163	28.3	40.7	0	9.3	0	18.8	28.8	19.2	1.7	37.7	37.2	19.0	31.3	31.0	24.2	15.5	39.2	26.6
Plowed under for green manure	286	19.2	35.2	0	4.8	0	25.0	10.7	14.7	1.3	30.7	21.7	8.0	16.8	22.2	24.2	4.0	28.0	18.8
Do	154	31.3	47.7	0	3.5	0	28.0	28.0	14.2	0	36.5	31.3	14.2	33.2	24.8	24.7	8.8	48.3	24.2
Corn:																			
Spring-plowed	282	27.3	31.8	0	2.5	0	16.0	21.0	11.3	.8	30.8	36.8	7.7	22.3	23.0	15.8	10.7	28.5	20.0
Do	153	23.0	22.7	0	8.3	0	15.7	18.2	14.2	1.5	34.2	20.2	14.5	20.2	20.8	18.2	10.0	26.7	19.5
Winter wheat:																			
Fall-plowed	402	25.7	30.7	0	7.7	0	18.0	14.8	18.3	4.3	30.3	35.0	14.2	20.8	19.8	15.7	15.8	33.3	19.7
Do	264	26.0	32.7	0	3.0	0	8.5	25.8	11.8	2.3	36.3	34.7	6.3	24.7	19.7	19.8	17.3	43.2	21.6
Do	167	30.5	45.7	0	9.7	0	18.8	31.3	20.2	8.3	37.7	46.5	21.0	33.2	32.7	28.5	17.7	46.5	29.2
Peanuts:																			
Spring-plowed	283	29.2	21.8	0	3.3	0	18.2	21.3	14.8	0	31.0	24.8	10.7	20.7	22.5	16.5	10.2	28.5	20.8
Cotton:																			
Spring-plowed	290	28.5	26.8	0	1.8	0	13.5	23.2	11.7	18.3	36.5	35.0	10.5	26.5	21.7	22.7	12.7	31.0	22.1
Fallow:																			
Summer-tilled	C. C.,[1] C, D	27.5	35.8	0	9.2	0	24.0	22.3	13.5	15.2	23.8	33.2	12.7	28.3	22.7	28.5	6.3	35.5	22.1
Do	155	26.8	32.2	0	8.8	0	21.8	17.5	5.0	18.5	15.7	26.8	9.7	27.5	19.2	26.7	3.8	31.2	18.5
Do	168	31.7	44.7	0	7.5	0	19.8	25.5	22.5	11.3	32.7	43.0	11.8	26.7	31.5	30.0	16.7	44.3	25.9
Summer-tilled, manured	288	23.5	30.7	0	2.5	0	20.7	17.3	9.2	12.3	23.3	34.0	4.3	20.8	25.8	30.8	2.7	38.5	19.4
Do	156	26.0	43.8	0	7.3	0	16.5	29.8	15.8	20.2	36.3	36.8	10.7	34.7	31.5	31.0	9.0	39.3	27.2
Summer-tilled, kafir topdressed	289	23.3	33.8	0	4.0	0	27.5	11.3	9.3	3.8	26.7	27.5	5.5	17.3	15.8	27.7	3.3	37.3	18.3
Winter rye:																			
Plowed under for green manure	151	28.3	38.8	0	8.3	0	25.5	23.8	11.8	13.5	30.5	35.2	12.3	25.7	30.8	21.3	8.2	39.7	23.1
Do	152	29.3	39.7	0	6.0	0	14.3	30.0	20.2	12.5	38.3	34.0	16.5	31.5	27.3	24.7	13.2	41.7	26.2

[1] C. C. indicates plots A to G only of the original continuous-cropping and alternate-cropping groups.

[2] 1 mark (′) on a capital letter or a number means 1 replication of the C. C. plot designated by that letter or the rotation designated by that number.

[3] Spring-plowed after 1940.

TABLE 22.—*Annual and average yields in pounds of kafir stover in rotation and tillage experiments, field A, Woodward, Okla., 1915–48*

Previous crop and tillage treatment	Rotation or plot	Acre yields in—																
		1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931
Kafir:																		
Spring-plowed	C. C.,[1] A	5,870	2,800	5,400	2,210	1,380	5,280	3,210	3,560	2,350	2,060	3,930	5,780	3,630	2,550	2,750	1,300	2,060
Do	160					2,280	5,780	1,880	2,380	2,130	2,360	3,550	4,780	2,140	2,410	2,260	1,100	2,080
Fall-plowed	C. C.,[1] B	6,470	2,890	6,000	1,830	2,440	5,150	3,650	4,360	2,460	1,990	2,930	6,000	4,580	2,730	2,980	1,150	2,810
Do	C. C.,[1] B′ [2]					4,010	6,340	4,590	2,730	3,130	3,140	4,660	7,490	4,480	2,640	2,450	1,830	2,460
Do	402	6,490	4,160	4,910	1,970	2,450	4,250	3,780	2,980	2,200	2,380	3,290	4,890	3,890	2,860	2,710	1,500	2,230
Fall-plowed, manured	H					2,430	7,260	3,300	3,880	3,010	2,630	4,180	9,230	7,430	4,040	4,080	2,240	2,990
Fall-plowed, subsoiled	C. C.,[1] E [3]	5,400	2,600	5,590	1,910	2,900	4,260	2,840	3,630	1,600	2,040	3,290	5,240	3,650	2,380	2,480	1,110	1,890
Listed	C. C.,[1] F	5,170	2,580	5,180	1,250	2,090	3,130	2,940	2,140	1,250	1,550	2,300	2,290	2,280	1,490	1,640	1,030	1,180
Disked and listed	C. C.,[1] G	4,690	2,970	4,960	1,330	2,930	3,490	3,150	2,410	1,390	2,330	3,110	2,100	2,540	1,650	1,650	1,040	1,330
Milo:																		
Spring-plowed	162					2,330	5,640	2,740	2,690	2,580	2,390	3,740	4,490	1,900	1,940	2,430	1,200	1,910
Do	165					2,450	6,560	3,940	2,280	3,100	2,100	3,700	5,800	4,080	2,410	2,830	1,060	2,860
Do	294					2,380	6,580	4,530	2,080	2,000	2,640	3,300	5,850	2,500	2,750	2,750	1,540	2,000
Fall-plowed	161					2,790	5,400	2,940	3,350	3,060	2,560	3,580	6,200	4,240	2,500	3,700	1,700	2,240
Cowpeas:																		
Spring-plowed	284					3,590	8,460	4,180	2,840	2,330	2,490	4,100	6,950	3,910	3,240	3,180	2,040	2,300
Do	285					4,550	6,250	6,350	2,590	2,940	2,900	4,280	6,800	3,390	3,310	2,440	1,630	2,850
Do	[2] 285′					4,250	6,180	2,910	2,310	2,080	2,060	3,240	5,290	3,380	2,780	2,990	1,340	1,890
Do	160					3,680	6,780	4,880	2,640	2,550	2,430	3,860	4,710	2,150	2,890	2,260	1,450	2,240
Do	169					4,760	6,510	5,190	3,010	2,690	2,390	5,200	6,410	4,680	4,210	3,400	1,740	3,380
Fall-plowed	163					3,710	6,850	5,940	3,330	3,300	2,890	5,290	6,540	5,550	4,280	3,340	1,790	2,810
Plowed under for green manure	286					3,750	7,040	3,140	2,480	2,660	1,740	3,630	5,510	5,410	2,480	3,440	1,630	2,200
Do	154					3,820	7,960	6,350	3,530	2,950	2,830	4,510	8,230	7,610	3,890	4,210	2,440	3,290
Corn:																		
Spring-plowed	282					7,040	6,090	5,050	2,800	1,030	2,910	2,990	5,490	3,750	2,880	3,000	1,340	2,490
Do	153					3,250	6,310	5,630	2,050	2,810	1,990	2,880	5,250	4,850	3,250	3,010	1,750	2,400
Winter wheat:																		
Fall-plowed	402	7,200	3,920	4,270	1,690	4,340	5,090	4,950	3,130	2,230	1,930	3,530	5,000	4,500	2,750	2,640	1,440	2,790
Do	264					4,000	5,540	5,500	1,610	2,630	2,360	4,060	8,050	5,540	2,950	3,460	1,980	2,750
Do	167					4,000	7,090	6,560	3,800	3,850	2,900	5,450	9,310	5,500	4,390	3,660	2,410	4,040
Peanuts:																		
Spring-plowed	283					3,260	6,730	5,560	2,590	2,680	3,040	4,530	6,700	5,480	3,200	3,240	1,740	2,510
Cotton:																		
Spring-plowed	290					3,320	5,980	5,190	2,830	2,790	3,010	2,960	7,310	5,800	3,230	3,330	2,590	2,340
Fallow:																		
Summer-tilled	C. C.,[1] C, D	5,840	3,160	7,190	2,010	2,560	5,300	2,950	4,330	2,880	2,340	3,480	7,200	4,940	3,280	3,080	1,930	2,560
Do	155					1,590	3,880	4,650	2,540	2,080	2,000	3,750	4,050	3,900	3,190	3,130	1,310	2,180
Do	168					4,380	7,640	5,380	2,450	3,210	3,060	4,680	7,150	5,340	3,590	3,290	2,580	2,660
Summer-tilled, manured	288					3,060	7,750	3,600	3,030	2,210	2,010	3,650	7,000	5,360	3,100	3,080	1,880	2,640
Do	156					4,750	8,660	6,980	4,040	4,150	3,560	6,260	9,440	7,880	4,830	4,640	3,030	4,540
Summer-tilled, kafir topdressed	289					3,580	7,650	4,600	3,000	2,580	2,130	3,900	6,850	4,910	2,910	3,580	1,580	2,390
Winter rye:																		
Plowed under for green manure	151					3,710	4,080	7,030	4,640	4,240	2,840	5,360	7,590	8,000	4,090	4,660	2,450	3,860
Do	152					4,530	4,560	6,460	4,010	3,910	1,860	4,200	7,760	6,230	3,850	4,140	2,630	4,390

Previous crop and tillage treatment	Rotation or plot	Acre yields in—																	
		1932	1933	1934	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	Average
Kafir:																			
Spring-plowed	C. C.,[1] A	1,350	2,640	3,000	2,190	2,650	2,790	2,360	2,680	1,560	3,100	3,320	3,140	3,490	2,510	3,250	2,080	4,350	3,017
Do	160	1,180	2,990	3,280	1,580	2,600	2,100	1,950	1,300	2,710	3,240	2,120	2,330	1,910	1,200	2,620	1,450	2,490	2,406
Fall-plowed	C. C.,[1] B	1,490	2,430	3,110	2,510	2,700	2,510	2,760	2,770	1,130	3,410	3,240	2,960	3,150	2,260	3,460	2,140	3,780	3,124
Do	C. C.,[1] B′ [2]	1,560	2,280	3,300	2,460	3,340	2,240	2,610	2,320	810	3,510	3,910	3,370	3,450	1,740	4,000	2,340	5,250	3,281
Do	402	1,100	2,450	2,830	1,880	2,650	2,290	2,560	2,480	1,190	3,160	2,920	3,080	3,140	2,100	3,090	2,150	4.450	2,955
Fall-plowed, manured	H	1,840	2,590	3,050	3,210	2,810	2,240	3,080	3,190	940	4,260	4,220	3,580	4,960	3,700	4,830	2,530	6,310	3,801
Fall-plowed, subsoiled	C. C.,[1] E [3]	1,240	2,600	2,980	1,910	2,700	2,480	2,000	2,160	1,690	2.410	2,250	2.340	2,390	1,860	2,930	1,500	3,580	2,701
Listed	C. C.,[1] F	790	2,760	2,530	930	740	2,100	1,590	1,200	1,310	2,480	3,450	1,940	2,000	2,390	2,540	1,140	2,230	2,106
Disked and listed	C. C.,[1] G	850	3,000	2,730	960	1,440	2,240	1,440	1,310	2,000	2,080	2,390	2,230	2,060	1,860	2,650	1,190	2,390	2,232
Milo:																			
Spring-plowed	162	1,180	3,580	3,780	1,780	2,550	2,610	2,050	1,690	2,440	3,110	2,490	2,600	2,480	1,780	2,550	1,540	2,900	2,570
Do	165	1,040	3,250	3,750	2,560	3,450	2,840	2,360	2,440	1,250	3,010	3,240	2,140	3,030	1,950	3,980	2,550	4,290	3,010
Do	294	1,010	2,440	3,160	1,900	3,240	2,480	1,680	1,880	1,310	2,660	3,110	2,340	2,920	1,900	3,530	1,710	4,310	2,749
Fall-plowed	161	1,400	2,400	3,190	2,510	2,860	2,480	3,080	2,780	1,310	4,140	2,870	3,380	3,680	2.430	3,660	2,780	4,810	3,134
Cowpeas:																			
Spring-plowed	284	1,450	3,980	3,830	2,590	3,130	2,700	2,560	2,510	1,420	2,900	3,710	3,230	3,690	2,560	5,550	1,800	4,790	3.400
Do	285	1,390	3,250	3,000	2,510	3,660	3,160	2,410	2,590	810	2,700	3,880	3,480	2,900	2,210	4,230	2,430	5,200	3,336
Do	[2] 285′	1,010	2,740	3,140	1,880	2,760	2,200	1,800	1,790	1,230	1,869	2,980	2,800	2,640	1,960	3.080	1,180	3,860	2,654
Do	160	1,100	4,280	3,580	1,640	2,980	2,380	2,000	1,860	1,380	2,630	2,950	2,790	2,380	1,680	3,620	1,260	3,150	2,806
Do	169	1,580	3,380	4,280	2,410	3,190	3,530	2,880	2,480	2,490	3,150	3,050	3,330	3,410	2,360	4,860	2,210	5,080	3,575
Fall-plowed	163	1,460	3,730	3,910	2,690	3,190	3,200	3,190	2,910	2,480	3,860	3,970	3,300	3,820	3,000	4,730	2,430	5,140	3,754
Plowed under for green manure	286	850	3,180	3,140	2,690	2,650	2,840	2,000	2,490	2,360	2,560	2,790	3,360	2,820	2,480	3,590	1,810	3,780	3,017
Do	154	1,790	4,790	3,710	2,940	3,710	3,340	2,310	3,040	1,560	4,160	3,740	3,510	4,120	3,540	6,250	2,160	7,250	4,118
Corn:																			
Spring-plowed	282	1,190	3,300	2,580	2,250	3,610	2,930	2,510	1,700	2,080	3,030	3,900	2,940	2,720	1,850	3,790	2,510	3,760	3,117
Do	153	1,280	3,760	3,160	2,490	2,980	3,030	2,760	2,730	2,860	3,850	1,950	3,110	3,850	2,090	3,560	3,050	4,080	3,201
Winter wheat:																			
Fall-plowed	402	1,080	2,460	3,050	2,300	2,910	2,560	2,660	2,900	2,300	2,730	3,780	3,490	2,840	2,180	4,340	2,850	4,620	3,249
Do	264	1,590	3,140	3,890	2,760	2,700	2,150	2,130	2,730	2,440	3,430	4,000	2,960	3,780	2,230	4,530	3,400	6,050	3,478
Do	167	1,830	3,790	4,530	2,900	3,660	3,660	3,490	2,860	3,240	5,110	5,270	3,730	4,250	2,700	5,400	2,800	7,130	4,310
Peanuts:																			
Spring-plowed	283	1,200	2,640	2,780	2,850	3,610	3,160	2,460	2,550	880	3,200	3,540	2,810	2,870	2,110	3,550	2,500	4,530	3,283
Cotton:																			
Spring-plowed	290	1,480	2,790	3,080	2,580	3,610	2,930	2,610	2,860	3,330	3,140	4,510	3,350	3,660	2,650	3,900	3,030	5,190	3,513
Fallow:																			
Summer-tilled	C. C.,[1] C, D	1,580	3,550	4,250	2,240	3,340	3,060	3,180	2,780	3,950	2,880	3,910	3,580	3,980	2,490	4,280	2,010	5,710	3,582
Do	155	1,760	3,740	3,860	1,800	3,760	2,750	2,660	2,290	3,050	2,460	3,630	3,340	2,650	2,400	3,920	1,330	4,700	2,945
Do	168	1,800	4,390	4,030	2,590	3,760	3,250	3,080	3,260	3,690	4,410	5,420	3,490	3,660	2,960	4,990	2,760	7,650	4,020
Summer-tilled, manured	288	1,410	3,140	3,940	2,680	3,340	2,510	3,080	2,460	3,400	2,550	4,010	3,090	4,900	2,360	4,960	1,630	5,490	3,444
Do	156	2,930	4,850	4,530	2,960	4,730	4,160	2,940	3,790	4,760	4,040	4,590	4,180	4,300	3,760	6,110	2,630	7,240	4,842
Summer-tilled, kafir topdressed	289	1,410	3,980	3,660	2,690	2,760	2,560	2,980	2,660	3,250	2,930	3,930	3,340	4,670	2,360	5,550	1,760	3,060	3,440
Winter rye:																			
Plowed under for green manure	151	2,140	4,190	4,080	2,690	3,980	3,660	3,390	3,400	4,260	3,990	4,720	3,740	4,010	3,330	5,380	2,600	6,610	4,291
Do	152	2,060	3,580	3,860	3,260	3,400	3,660	2,360	3,090	3,360	3,180	3,900	3,330	4,040	2,630	4,990	3,030	6,200	3,949

[1] C. C. indicates plots A to G only of the original continuous-cropping and alternate-cropping groups.

[2] 1 mark (′) on a capital letter or a number means 1 replication of the C. C. plot designated by that letter or the rotation designated by that number.

[3] Spring-plowed after 1940.

TABLE 23.—*Annual and average yields in bushels of kafir grain in rotation and tillage experiments, field B, Woodward, Okla., 1933–48*

Previous crop and tillage treatment	Rotation or plot	Acre yields in—																Average
		1933	1934	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	
Kafir:																		
Spring-plowed	I–28	31.0	0	7.7	0	16.0	25.5	13.2	0	38.8	31.5	18.8	24.7	27.7	20.5	12.3	33.5	18.8
Do	E–41					15.2	25.5	5.7	0	43.0	30.2	10.8	24.2	16.8	16.8	13.3	27.3	19.1
Fall-listed, leveled, old furrows nosed out	I–25	29.8	0	15.0	0	21.5	37.3	14.2	0	34.2	33.3	14.5	22.3	20.8	16.8	12.7	29.2	18.9
Fall-listed, leveled, split at planting	J–25	35.0	0	16.7	0	22.2	34.3	16.4	0	33.8	29.3	14.2	30.5	17.5	19.0	12.3	29.7	19.4
Spring-listed, split at planting	D–39					14.3	30.5	7.3	0	35.7	29.0	12.0	22.7	16.7	10.0	11.8	30.2	18.4
Early-spring-listed, leveled, old furrows nosed out.	I–26	33.0	0	16.3	0	24.7	36.7	16.3	0	32.2	33.0	16.7	21.7	20.2	16.3	13.3	28.5	19.3
Early-spring-listed, split at planting	J–26	26.3	0	11.8	0	21.8	31.5	10.5	0	26.7	31.7	9.2	26.7	17.2	15.7	9.2	24.8	16.4
Spring-basin-listed, contoured	D–41					18.8	32.3	12.6	0	33.0	37.7	17.8	30.2	22.2	15.5	12.8	39.3	22.7
Early-spring-disked, listed at planting	I–27	30.5	0	19.2	0	30.5	31.3	15.2	0	26.0	28.8	17.5	25.5	16.5	16.0	11.7	20.5	18.1
Wheat:																		
One-wayed	264	31.5	0	7.3	0	13.5	29.7	12.2	0	39.2	37.3	16.3	31.8	25.7	16.7	13.5	44.8	20.0
Fallow:																		
Summer-tilled	287			6.5	0	20.5	24.2	8.2	3.0	34.7	36.8	7.5	29.2	28.0	20.2	14.7	39.7	19.5

TABLE 24.—*Annual and average yields in bushels of milo grain in rotation and tillage experiments, field A, Woodward, Okla., 1915–48*

Previous crop and tillage treatment	Rotation or plot	Acre yields in—																
		1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931
Milo:																		
Spring-plowed	C. C.,[1] A	38.1	7.6	20.3	5.9	19.6	14.7	32.3	9.1	4.5	27.2	12.5	34.3	38.1	17.2	17.9	11.9	11.9
Fall-plowed	C. C.,[1] B	42.8	7.8	22.6	7.8	25.9	11.2	33.4	11.0	3.4	31.0	21.6	44.4	50.5	19.7	17.9	13.6	12.9
Do	C. C.,[1] B′ [2]					13.8	23.7	27.6	8.0	6.9	26.5	12.3	35.1	47.1	15.5	13.4	10.2	12.8
Do	C. C.,[1] B″ [2]					16.5	7.1	30.2	5.6	0	23.7	11.0	23.3	60.2	14.8	14.5	4.3	10.5
Fall-plowed and manured	H					15.6	17.5	34.3	6.0	0	19.4	8.4	16.6	60.5	8.8	8.6	6.9	8.8
Fall-plowed, subsoiled	C. C.,[1] E [3]	40.0	4.0	27.9	5.6	18.0	18.1	26.5	8.6	5.4	29.7	14.7	34.5	38.8	19.8	17.8	12.2	9.1
Listed	C. C.,[1] F	29.7	0	23.1	2.9	15.8	17.9	17.9	6.9	3.0	14.7	6.5	22.8	22.2	7.9	11.2	8.8	9.5
Disked and listed	C. C.,[1] G	32.0	0	21.1	2.4	13.0	19.4	16.2	6.9	3.7	19.8	17.7	25.0	20.3	7.1	11.2	9.3	8.6
Cowpeas:																		
Spring-plowed	162					36.1	28.0	33.4	14.0	7.8	23.7	27.6	41.8	31.7	21.7	17.8	14.7	19.7
Fall-plowed	161					37.1	17.5	40.1	11.4	12.9	35.6	39.0	55.6	46.6	35.3	26.0	18.1	25.0
Kafir:																		
Spring-plowed	168					33.7	7.5	34.3	16.6	5.4	36.6	26.9	50.4	49.3	29.5	22.9	22.9	26.7
Do	169					28.2	26.9	45.0	23.7	13.4	36.4	22.2	56.9	47.2	19.8	26.0	17.1	16.2
Do	294					22.4	20.9	33.8	11.4	0	28.0	22.0	46.8	54.5	20.5	18.8	9.1	19.1
Fall-plowed	163					36.2	20.2	49.3	15.9	10.8	40.5	32.8	56.5	51.9	27.8	29.3	21.2	18.1
Wheat:																		
Fall-plowed	166					35.7	21.8	48.3	21.8	17.0	42.0	35.4	53.2	70.5	15.7	32.8	30.7	27.8
Do	263					23.5	13.8	32.8	7.3	0	29.7	21.8	34.9	54.8	20.0	12.1	0	14.0
Fallow:																		
Summer-tilled	C. C.,[1] C, D	45.0	5.7	23.2	8.6	13.8	28.2	29.7	11.0	2.8	28.7	21.1	45.5	35.0	24.3	16.0	12.6	9.7
Do	165					28.1	35.1	39.7	9.1	10.3	30.6	31.5	51.1	50.2	20.7	27.2	20.5	20.3
Do	297					18.2	31.5	29.1	9.1	0	25.6	10.8	36.9	37.1	8.4	12.2	8.8	6.7
Summer-tilled, manured	298					14.4	26.3	30.0	8.6	0	21.3	6.5	32.3	37.1	9.3	11.7	11.9	3.3

Previous crop and tillage treatment	Rotation or plot	Acre yields in—																	
		1932	1933	1934	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	Average
Milo:																			
Spring-plowed	C. C.,[1] A	21.6	22.2	4.1	9.5	0	16.9	16.0	7.9	1.0	22.6	20.7	11.4	21.2	14.5	11.2	10.3	31.9	16.7
Fall-plowed	C. C.,[1] B	25.9	13.6	1.0	5.2	0	15.7	18.3	7.6	.7	25.5	20.5	11.0	28.4	17.1	10.2	13.1	34.1	18.4
Do	C. C.,[1] B′[2]	24.1	19.1	0	2.4	0	14.7	14.5	1.6	1.0	21.4	23.8	10.3	23.8	16.6	11.4	9.1	30.3	15.9
Do	C. C.,[1] B″[2]	25.0	13.8	0	3.6	0	10.0	17.9	4.0	.5	27.8	22.1	10.0	32.1	16.9	15.3	11.0	38.1	15.7
Fall-plowed and manured	H	27.2	15.3	0	2.2	0	16.2	4.3	4.3	1.0	16.0	19.7	5.9	22.1	18.8	8.6	2.8	39.8	13.9
Fall-plowed, subsoiled	C. C.,[1] E[3]	24.7	10.2	1.4	4.5	0	16.6	16.0	6.6	1.0	20.5	17.9	12.8	23.4	15.2	7.1	13.4	26.7	16.1
Listed	C. C.,[1] F	17.9	15.3	4.5	4.8	0	16.4	18.6	8.3	5.2	12.8	14.7	10.5	16.9	12.8	10.3	6.9	19.0	12.2
Disked and listed	C. C.,[1] G	16.9	15.2	3.4	4.3	0	16.6	14.0	8.3	3.1	14.8	15.2	7.9	16.4	12.8	7.8	7.9	20.1	12.3
Cowpeas:																			
Spring-plowed	162	20.9	22.6	14.5	13.1	0	19.0	26.0	13.8	9.5	15.2	17.2	16.0	15.5	17.9	10.0	11.9	24.1	19.5
Fall-plowed	161	25.7	25.7	13.6	16.4	0	15.2	29.8	12.2	3.6	30.7	30.0	23.4	24.7	23.4	15.3	18.3	31.9	24.7
Kafir:																			
Spring-plowed	168	28.3	20.0	6.7	7.1	0	18.3	20.3	13.8	.5	25.0	26.6	16.0	23.8	20.5	14.0	18.8	34.3	21.9
Do	169	26.9	27.6	9.3	16.9	0	14.7	35.2	15.5	6.0	32.1	24.1	14.7	21.6	22.4	11.2	19.0	31.7	23.6
Do	294	18.8	14.5	3.6	3.6	0	12.2	18.3	11.9	1.4	25.5	18.3	13.1	19.7	22.1	8.6	17.2	26.6	18.1
Fall-plowed	163	28.3	20.5	11.2	14.7	0	15.3	28.6	17.1	5.9	31.2	26.4	20.5	23.1	22.1	13.4	18.6	32.9	24.7
Wheat:																			
Fall-plowed	166	26.9	32.1	13.6	18.8	0	14.3	32.6	25.5	15.3	28.1	36.7	25.2	27.2	27.8	13.4	19.8	43.6	28.5
Do	263	27.2	19.5	1.7	2.4	0	8.4	9.7	4.0	1.7	23.4	21.6	8.6	30.7	19.1	10.9	14.5	49.1	17.2
Fallow:																			
Summer-tilled	C. C.,[1] C, D	24.7	17.2	5.2	6.2	0	19.0	16.6	5.3	3.3	17.4	20.9	10.9	25.0	18.3	10.5	10.3	33.6	17.8
Do	165	25.7	22.6	7.6	12.2	0	16.4	29.3	10.9	9.5	26.9	25.7	16.0	26.4	21.7	13.8	20.0	36.0	23.2
Do	297	16.4	27.8	0	4.5	0	15.2	12.9	3.1	4.3	14.5	20.5	6.7	14.8	16.2	10.3	9.5	32.1	14.8
Summer-tilled, manured	298	25.5	20.3	0	2.6	0	12.8	10.3	1.0	3.6	18.1	22.1	4.3	24.0	18.8	13.1	4.5	39.0	14.4

[1] C. C. indicates plots A to G only of the original continuous-cropping and alternate-cropping groups.

[2] 1 mark (′) on a capital letter or a number means 1 replication of the C. C. plot designated by that letter or the rotation designated by that number; 2 such marks mean 2 replications.

[3] Spring-plowed after 1940.

TABLE 25.—*Annual and average yields in bushels of milo grain in rotation and tillage experiments, field B, Woodward, Okla., 1933–48*

Previous crop and tillage treatment	Rotation or plot	Variety [1]	Acre yields in—																Average
			1933	1934	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	
Milo (in rows 3½ feet apart):																			
Spring-plowed	E-46	Dwarf Yellow	-----	-----	3.3	0	12.2	15.2	1.6	1.4	38.1	32.4	20.5	26.0	20.5	11.7	19.7	28.1	16.5
Do	E-39	Wheatland	-----	-----	8.4	2.2	17.4	32.4	22.2	7.8	37.1	22.1	15.7	36.0	23.3	13.4	20.0	41.6	21.4
Do	E-40	Sooner	-----	-----	20.0	1.9	17.8	44.0	22.9	12.9	29.8	27.6	24.0	27.6	18.8	12.8	16.4	22.2	21.3
Spring-listed [2]	D-40	Dwarf Yellow	-----	-----	-----	-----	16.6	37.8	9.3	14.5	34.7	30.9	21.2	30.2	21.4	13.4	16.2	37.8	23.7
Contoured, basin-listed	D-45	do	-----	-----	-----	-----	15.0	30.0	1.8	7.9	40.9	34.5	24.8	27.8	22.8	13.4	19.0	49.0	23.9
Wheat (milo in rows 3½ feet apart):																			
Early one-wayed	257	do	29.0	5.2	15.5	0	10.5	31.7	17.8	3.6	43.6	38.8	22.6	36.4	29.1	16.0	21.2	49.7	23.2
Fallow (milo in rows 3½ feet apart):																			
Summer-tilled	297	do	-----	-----	-----	-----	15.5	30.3	7.6	8.3	35.3	28.4	22.4	27.4	30.2	13.6	22.4	37.2	23.2
Summer-tilled, contoured, basin-listed	297	do	-----	-----	-----	-----	14.8	34.5	5.5	20.5	41.4	41.4	18.1	18.6	31.0	19.8	26.9	38.4	25.9
Wheat (milo in rows 16½ feet apart):																			
Early one-wayed	E-33 or 34	do	-----	-----	4.1	2.4	6.9	16.2	10.3	10.3	16.2	14.5	10.0	10.7	14.1	5.9	10.0	15.7	10.5
Do	E-35 or 36	Wheatland	-----	-----	4.1	1.0	3.1	16.6	9.0	6.6	10.3	7.4	5.7	6.6	7.2	2.1	6.9	8.6	6.8
Wheat, same season (milo in rows 16½ feet apart):																			
Early one-wayed	E-37	do	-----	-----	0	0	0	14.5	1.7	0	10.7	6.4	1.0	4.5	3.8	.2	.9	9.8	3.8
Do	E-38	Sooner	-----	-----	0	0	0	12.1	3.1	.7	3.1	4.1	2.2	6.6	2.4	.7	.5	8.6	3.2

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[1] Three varieties of milo are included: Dwarf Yellow (crookneck); Sooner, a very early crookneck type; and Wheatland, a short variety adapted to combine harvesting.

[2] Split at planting.

TABLE 26.—*Annual and average total yields in pounds of sorgo in rotation and tillage experiments, field A, Woodward, Okla., 1915–48*

Previous crop and tillage treatment	Rotation or plot	Acre yields in—																
		1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931
Sorgo:																		
Spring-plowed	C. C.,[1] A	6,720	4,280	4,110	3,500	6,500	10,000	6,880	5,610	5,000	8,950	7,280	10,810	9,010	5,880	6,550	2,390	3,070
Fall-plowed	C. C.,[1] B	7,890	5,200	4,000	5,100	7,750	10,630	7,940	6,190	5,560	8,450	11,330	12,690	12,310	6,960	8,210	3,750	4,280
Fall-plowed, subsoiled	C. C.,[1] E [2]	8,100	6,330	4,200	4,170	12,060	11,380	8,750	6,710	7,380	8,030	11,190	13,250	13,310	8,040	8,240	4,320	4,960
Listed	C. C.,[1] F	7,890	5,200	4,500	2,700	6,060	9,440	7,380	7,180	3,130	7,490	4,900	9,630	7,310	5,450	6,710	2,030	3,060
Disked and listed	C. C.,[1] G	7,000	6,390	4,670	3,500	7,500	11,000	8,440	6,910	3,380	9,180	8,600	11,380	8,250	6,350	8,200	2,690	4,010
Fallow:																		
Summer-tilled	C. C.,[1] C, D	9,110	5,610	6,440	3,220	8,250	13,500	7,130	7,050	9,940	7,960	12,990	14,750	15,690	7,750	8,110	4,440	5,740

Previous crop and tillage treatment	Rotation or plot	Acre yields in—																
		1932	1933	1934	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	Average
Sorgo:																			
Spring-plowed	C. C.,[1] A	4, 660	3, 560	4, 080	3, 140	3, 840	4, 730	4, 100	3, 150	3, 890	5, 560	5, 580	3, 680	5, 260	4, 670	4, 910	2, 340	7, 570	5, 331
Fall-plowed	C. C.,[1] B	5, 380	4, 240	4, 250	4, 230	3, 430	5, 160	5, 140	4, 060	1, 250	6, 740	5, 780	4, 270	6, 840	5, 310	5, 260	2, 960	9, 340	6, 230
Fall-plowed, subsoiled	C. C.,[1] E [2]	6, 340	4, 130	4, 140	3, 210	4, 640	5, 000	5, 460	4, 630	1, 380	7, 490	5, 310	4, 270	6, 640	4, 990	4, 440	7, 940	2, 630	6, 561
Listed	C. C.,[1] F	5, 840	2, 860	2, 630	2, 490	40	2, 850	4, 980	2, 740	1, 350	6, 190	4, 510	2, 760	5, 610	3, 570	3, 850	2, 190	7, 490	4, 765
Disked and listed	C. C.[1], G	6, 440	2, 450	4, 300	3, 480	2, 310	4, 930	5, 240	4, 040	2, 780	6, 010	6, 150	4, 170	6, 980	5, 230	5, 210	2, 430	8, 150	5, 816
Fallow:																			
Summer-tilled	C. C.[1], C, D	5, 600	6, 750	5, 360	4, 890	5, 690	5, 860	5, 960	5, 110	6, 760	6, 370	6, 430	5, 810	8, 040	6, 270	5, 940	3, 410	10, 530	7, 425

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[1] C. C. indicates plot A to G only of the original continuous-cropping and alternate-cropping groups.

[2] Spring-plowed after 1940.

TABLE 27.—*Annual and average yields in pounds of broomcorn brush in rotation and tillage experiments, field A, Woodward, Okla., 1915–48*

Previous crop and tillage treatment	Rotation or plot	Acre yields in —																
		1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931
Broomcorn:																		
Spring-plowed	C. C.,[1] A	830	210	380	290	310	510	610	310	210	450	160	830	810	340	280	110	150
Fall-plowed	C. C.,[1] B	780	250	360	220	330	460	580	330	160	680	260	750	710	300	250	130	180
Fall-plowed, subsoiled	C. C.,[1] E [2]	830	300	430	370	420	610	680	360	240	830	510	940	830	450	390	200	340
Listed	C. C.,[1] F	860	320	400	370	440	650	630	240	300	300	0	640	650	350	340	160	300
Disked and listed	C. C.,[1] G	820	310	390	380	440	650	740	380	310	640	600	940	880	460	380	240	460
Fallow:																		
Summer-tilled	C. C.,[1] C, D	820	250	330	340	320	640	610	360	110	700	410	830	850	310	320	180	260

Previous crop and tillage treatment	Rotation or plot	Acre yields in —																	
		1932	1933	1934	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	Average
Broomcorn:																			
Spring-plowed	C. C.,[1] A	450	440	190	110	0	260	360	160	0	390	460	160	430	340	200	100	530	334
Fall-plowed	C. C.,[1] B	440	450	180	200	0	250	300	130	0	410	400	90	360	300	190	110	540	326
Fall-plowed, subsoiled	C. C.,[1] E [2]	560	400	190	140	0	260	440	240	0	460	390	210	490	260	140	230	610	404
Listed	C. C.,[1] F	590	430	210	30	0	160	240	330	60	590	310	200	300	280	230	340	640	350
Disked and listed	C. C.,[1] G	550	380	350	110	0	430	200	390	100	400	580	280	580	430	360	300	630	444
Fallow:																			
Summer-tilled	C. C.,[1] C, D	460	510	230	110	0	290	400	210	110	380	510	160	390	400	210	100	590	374

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[1] C. C. indicates plots A to G only of the original continuous-cropping and alternate-cropping groups.

[2] Spring-plowed after 1940.

TABLE 28.—*Annual and average yields in pounds of broomcorn stover in rotation and tillage experiments, field A, Woodward, Okla., 1915–48*

Previous crop and tillage treatment	Rotation or plot	Acre yields in —																
		1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931
Broomcorn:																		
Spring-plowed	C. C.,[1] A	5, 500	1, 440	2, 890	1, 500	2, 690	4, 380	3, 500	1, 310	2, 160	3, 130	900	3, 880	6, 190	2, 910	2, 030	1, 300	1, 680
Fall-plowed	C. C.,[1] B	5, 610	1, 250	2, 830	1, 200	2, 810	4, 060	3, 380	1, 060	2, 960	5, 000	3, 050	3, 450	5, 560	2, 850	1, 940	1, 250	1, 800
Fall-plowed, subsoiled	C. C.,[1] E [2]	6, 000	1, 610	3, 000	2, 000	3, 250	5, 500	4, 440	1, 130	3, 580	5, 940	3, 110	4, 280	6, 630	3, 680	2, 240	1, 930	2, 250
Listed	C. C.,[1] F	5, 550	1, 400	3, 050	1, 050	3, 060	2, 560	3, 380	1, 060	1, 700	2, 440	1, 750	2, 840	4, 380	2, 610	1, 680	1, 130	1, 990
Disked and listed	C. C.,[1] G	6, 170	1, 720	3, 000	1, 300	3, 170	2, 810	3, 250	1, 380	1, 380	3, 810	1, 780	3, 980	5, 190	3, 600	2, 250	1, 730	2, 960
Fallow:																		
Summer-tilled	C. C.,[1] C, D	5, 000	1, 170	3, 500	1, 390	3, 000	3, 560	3, 060	1, 190	3, 760	5, 190	1, 650	4, 550	6, 750	3, 450	1, 750	1, 860	2, 050

Previous crop and tillage treatment	Rotation or plot	Acre yields in —																
		1932	1933	1934	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	Average
Broomcorn:																			
Spring-plowed	C. C.,[1] A	3, 750	2, 800	1, 560	1, 640	560	2, 310	2, 630	1, 940	1, 130	3, 690	4, 850	2, 340	2, 230	2, 830	3, 360	2, 150	4, 160	2, 686
Fall-plowed	C. C.,[1] B	3, 380	2, 680	1, 630	2, 130	1, 190	2, 560	2, 060	1, 810	750	3, 250	4, 250	1, 560	2, 260	2, 730	3, 590	1, 830	3, 590	2, 686
Fall-plowed, subsoiled	C. C.,[1] E [2]	3, 960	2, 730	2, 000	2, 610	1, 690	2, 750	2, 940	2, 190	560	4, 190	3, 960	2, 290	2, 410	2, 430	2, 990	3, 180	4, 390	3, 172
Listed	C. C.,[1] F	3, 760	2, 740	1, 690	680	60	1, 000	2, 190	1, 930	810	4, 500	3, 920	2, 400	2, 040	3, 310	2, 700	2, 450	3, 360	2, 387
Disked and listed	C. C.,[1] G	3, 890	2, 590	1, 940	2, 180	900	2, 310	1, 940	2, 120	1, 250	4, 250	5, 160	2, 260	2, 300	3, 610	3, 450	2, 380	4, 440	2, 837
Fallow:																			
Summer-tilled	C. C.,[1] C, D	3, 880	3, 550	2, 250	2, 560	1, 690	2, 500	2, 630	2, 190	940	4, 000	4, 340	2, 160	2, 310	2, 630	3, 710	1, 800	4, 660	2, 961

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[1] C. C. indicates plots A to G only of the original continuous-cropping and alternate-cropping groups.
[2] Spring-plowed after 1940.

Table 29.—*Inches of available water present at planting time (about June 15) on four plots continuously or alternately cropped to milo, Woodward, Okla., 1920–45*

Year	Available water in first 4 feet of soil on—				Year	Available water in first 4 feet of soil on—			
	Spring-plowed land	Fall-plowed land	Fallowed land, cropped year	Fallowed land, fallow year		Spring-plowed land	Fall-plowed land	Fallowed land, cropped year	Fallowed land, fallowed year
1920	4.23	3.67	4.38	3.10	1934	3.25	4.00	4.11	3.95
1921	5.57	5.39	4.97	5.27	1935	2.88	3.87	3.89	3.61
1922	3.81	3.89	4.06	2.77	1936	3.89	4.32	4.21	4.41
1923	4.86	4.73	4.51	4.92	1937	4.15	4.06	3.74	4.26
1924	3.80	4.02	4.13	4.36	1938	4.11	4.28	4.39	3.89
1925	3.14	4.13	3.74	3.27	1939	4.45	4.17	3.85	4.64
1926	4.36	4.32	4.66	3.95	1940	3.03	2.26	4.24	2.36
1927	4.43	5.31	4.90	5.12	1941	5.37	5.37	5.11	5.44
1928	4.73	4.68	5.22	4.41	1942	4.15	4.69	4.54	4.68
1929	3.31	3.96	3.70	4.30	1943	4.66	4.41	5.03	4.84
1930	3.44	4.79	4.92	4.39	1944	4.10	4.36	4.32	3.57
1931	3.25	4.30	3.98	3.74	1945	4.43	4.47	3.78	4.53
1932	3.98	4.90	4.94	4.68					
1933	1.87	2.04	3.20	2.36	Average	3.97	4.25	4.33	4.11

TABLE 30.—*Annual and average yields in bushels of corn grain in rotation and tillage experiments, fields A and B, Woodward, Okla., 1915–48*

Previous crop and tillage treatment	Rotation or plot	Acre yields in— 1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931
Field A:																		
Corn:																		
Spring-plowed	C. C.,[1] A	26.1	0	0	0	0	17.7	18.3	2.9	10.9	9.7	1.3	20.7	23.0	23.7	19.7	2.3	10.4
Fall-plowed	C. C.,[1] B	20.4	0	0	0	0	16.4	16.6	1.3	5.0	10.7	4.0	20.6	20.9	22.9	21.4	3.7	11.1
Fall-plowed, subsoiled	C. C.,[1] E	21.3	0	0	0	0	10.5	19.1	2.6	3.0	10.7	8.3	18.0	25.0	22.0	19.4	4.9	12.6
Listed	C. C.,[1] F	19.6	0	0	0	0	14.1	12.0	1.3	1.4	7.1	1.9	13.4	17.3	15.6	11.9	0	4.3
Disked and listed	C. C.,[1] G	17.0	0	0	0	0	10.1	10.0	.7	.9	5.6	2.3	11.9	12.1	9.4	7.1	0	2.0
Kafir:																		
Spring-plowed	282					0	3.2	26.4	3.9	6.4	10.0	1.8	21.4	20.9	21.4	16.3	1.6	7.1
Do	[2]152	17.4	10.4	0	0	0	15.6	22.6	3.3	5.1	8.1	6.3	18.0	19.9	26.4	19.4	5.6	12.6
Wheat:																		
Fall-plowed	262					0	9.5	25.5	1.8	12.5	11.4	3.6	23.8	14.4	22.9	17.0	3.2	5.7
Do	[2]153	19.4	6.0	0	0	0	15.9	18.3	2.3	2.0	7.3	4.1	14.1	11.9	22.1	14.6	2.0	10.4
Fallow:																		
Summer-tilled	C. C.,[1] C, D	24.4	0	0	0	0	20.8	23.7	3.3	8.6	10.6	5.6	21.6	22.1	22.0	15.7	2.9	10.6
Field B:																		
Wheat:																		
Early one-wayed	35																	

Previous crop and tillage treatment	Rotation or plot	Acre yields in— 1932	1933	1934	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	Average
Field A:																			
Corn:																			
Spring-plowed	C. C.,[1] A	17.6	0	0	0	0	0	22.7	8.7	0.1	15.6	14.4	7.7	15.0	8.4	3.7	11.1	22.3	9.8
Fall-plowed	C. C.,[1] B	16.4	0	0	0	0	0	20.9	9.0	.1	17.7	12.7	9.9	16.6	8.4	2.9	9.1	20.6	9.4
Fall-plowed, subsoiled	C. C.,[1] E	15.7	0	0	0	0	0	16.9	9.1	.7	17.6	14.7	9.9	18.3	9.9	5.7	6.9	18.4	9.4
Listed	C. C.,[1] F	5.6	0	0	0	0	0	13.0	4.3	2.6	6.1	7.1	4.9	7.6	3.0	1.3	3.3	7.7	5.5
Disked and listed	C. C.,[1] G	3.6	0	0	0	0	0	9.9	2.6	2.6	5.1	4.9	4.3	8.3	2.3	.7	1.9	6.6	4.2
Kafir:																			
Spring-plowed	282	15.0	0	0	0	0	0	19.3	5.0	.1	9.0	12.7	13.4	17.0	1.9	1.6	4.7	16.6	8.6
Do	[2]152	14.4	0	0	0	0	0	18.7	5.9	.1	17.6	12.9	7.7	14.1	7.1	1.3	9.1	18.6	9.4
Wheat:																			
Fall-plowed	262	17.3	0	0	0	0	0	23.0	4.1	.1	12.7	9.4	9.9	11.4	6.3	4.3	7.3	24.4	9.4
Do	[2]153	10.7	0	0	0	0	0	16.1	5.1	.6	14.1	13.3	7.9	11.4	6.0	2.4	7.4	15.0	7.7
Fallow:																			
Summer-tilled	C. C.,[1] C, D	13.7	0	0	0	0	0	19.7	9.4	3.3	8.7	10.6	8.6	13.3	6.9	3.3	3.0	15.1	9.0
Field B:																			
Wheat:																			
Early one-wayed	35		0	0	0	0	0	22.7	10.0	0	27.6	15.7	7.7	18.6	9.3	2.7	14.3	20.9	9.3

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[1] C. C. indicates plots A to G only of the original continuous-cropping and alternate-cropping groups.

[2] Corn in double-spaced rows.

TABLE 31.—*Annual and average yields in pounds of corn stover in rotation and tillage experiments, fields A and B, Woodward, Okla., 1915–48*

Previous crop and tillage treatment	Rotation or plot	Acre yields in—																
		1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931
Field A:																		
Corn:																		
Spring-plowed	C. C.,[1] A	2,830	4,940	0	1,670	2,190	2,240	1,230	490	2,110	580	1,040	2,430	3,260	2,280	1,440	1,050	1,460
Fall-plowed	C. C.,[1] B	2,180	5,300	0	1,850	2,130	1,780	1,530	790	1,210	810	2,660	2,130	3,480	2,590	1,810	1,190	1,410
Fall-plowed, subsoiled	C. C.,[1] E	2,110	5,940	0	2,220	2,630	2,030	1,410	700	1,350	880	1,930	1,680	3,060	1,960	1,580	1,230	1,310
Listed	C. C.,[1] F	1,680	3,150	0	1,300	1,440	1,190	1,160	480	650	750	2,060	1,190	1,910	1,350	1,110	750	1,010
Disked and listed	C. C.,[1] G	1,310	3,110	0	1,170	1,810	1,490	800	450	560	640	960	1,240	1,590	1,090	1,130	630	860
Kafir:																		
Spring-plowed	282	---	---	---	---	2,100	2,830	1,780	730	1,610	860	2,380	3,380	2,350	2,250	1,490	1,080	1,500
Do	[2] 152	1,680	2,620	0	1,700	1,420	2,280	1,620	770	1,340	710	2,500	2,340	3,110	2,600	1,690	1,160	1,320
Wheat:																		
Fall-plowed	262	---	---	---	---	2,100	3,160	1,780	1,380	2,940	1,080	1,750	2,960	4,490	2,460	1,560	1,110	2,040
Do	[2] 153	1,640	2,430	0	1,350	1,250	2,010	1,620	840	1,310	1,040	2,030	2,010	2,720	2,250	1,530	1,200	1,370
Fallow:																		
Summer-tilled	C. C.,[1] C, D	2,340	4,890	2,300	1,950	2,310	2,310	1,710	900	2,400	1,080	2,050	2,610	2,700	2,090	1,400	1,230	1,580
Field B:																		
Wheat:																		
Early one-wayed	35	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

Previous crop and tillage treatment	Rotation or plot	Acre yields in—																	
		1932	1933	1934	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	Average
Field A:																			
Corn:																			
Spring-plowed	C. C.,[1] A	1,710	560	1,690	2,060	1,310	1,060	2,040	2,190	1,930	1,410	2,180	1,210	1,580	1,410	1,610	2,160	1,380	1,727
Fall-plowed	C. C.,[1] B	1,730	810	1,810	2,130	1,310	1,130	1,790	2,180	1,930	1,570	1,860	1,310	1,650	1,470	1,490	1,860	1,250	1,769
Fall-plowed, subsoiled	C. C.,[1] E	1,710	750	2,000	1,940	1,380	1,250	1,390	2,250	1,640	1,580	2,720	1,120	1,720	1,310	1,850	1,780	1,210	1,754
Listed	C. C.,[1] F	930	810	500	1,000	810	690	1,150	1,560	1,570	950	1,130	600	780	790	1,100	1,090	840	1,102
Disked and listed	C. C.,[1] G	750	940	560	880	560	500	1,000	1,430	1,200	640	1,540	580	980	720	1,140	1,000	850	1,003
Kafir:																			
Spring-plowed	282	1,830	630	1,940	2,190	1,380	810	1,900	1,560	1,680	1,250	1,740	500	1,620	680	1,330	1,610	1,090	1,603
Do	[2] 152	1,840	450	1,700	2,100	1,350	1,000	1,590	1,900	1,790	1,900	2,040	810	1,060	900	1,160	1,860	1,350	1,578
Wheat:																			
Fall-plowed	262	2,160	1,750	1,880	1,880	1,440	1,310	2,200	2,060	2,050	1,740	2,720	1,370	1,700	1,810	1,830	2,180	1,600	2,016
Do	[2] 153	2,250	1,150	1,250	1,700	1,550	1,000	1,710	1,900	2,110	1,470	2,450	1,000	1,650	1,080	1,380	1,830	1,250	1,569
Fallow:																			
Summer-tilled	C. C.,[1] C, D	1,730	690	1,810	2,130	1,440	1,560	2,000	2,320	2,710	1,200	1,760	1,280	1,320	1,460	1,650	1,600	1,190	1,874
Field B:																			
Wheat:																			
Early one-wayed	35	---	2,130	2,560	2,690	1,810	940	2,230	2,940	1,810	2,380	2,900	2,020	1,830	2,040	2,000	2,630	1,480	2,149

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[1] C. C. indicates plots A to G only of the original continuous-cropping and alternate-cropping groups.
[2] Corn in double-spaced rows.

TABLE 32.—*Annual and average yields in pounds of cowpea hay in rotation and tillage experiments, fields A and B, Woodward, Okla., 1919–48*

Previous crop and tillage treatment	Rotation number	Acre yields in—															
		1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931	1932	1933	1934
Field A:																	
Kafir:																	
Spring-plowed	160	3,380	1,850	3,600	1,450	1,550	3,300	1,400	1,650	3,500	1,450	1,800	1,700	1,300	2,000	2,100	1,250
Do	162	2,370	2,100	3,450	1,700	1,150	2,900	1,300	2,009	3,050	1,400	1,350	1,700	1,200	1,950	2,150	1,700
Do	167	3,060	2,200	4,550	1,900	1,250	4,100	1,650	2,050	4,400	2,100	1,900	1,700	1,900	3,000	2,000	1,750
Do	284	2,350	1,750	3,250	1,000	1,000	2,900	1,350	1,650	3,450	1,650	1,550	1,510	1,450	1,850	3,050	1,450
Do	285	3,100	1,950	3,250	800	1,250	3,300	1,450	2,000	3,750	1,700	1,500	1,730	1,500	2,800	1,800	1,600
Do	[1] 285′	4,060	1,600	3,150	1,250	1,000	2,250	1,300	1,150	2,750	1,350	1,500	1,270	1,300	2,000	2,600	1,200
Fall-plowed	161	2,560	2,100	3,500	1,900	1,000	3,650	1,820	2,100	3,150	1,600	1,650	1,880	1,500	2,500	2,200	1,450
Milo:																	
Spring-plowed	166	2,630	1,750	4,350	2,500	1,400	4,060	1,650	2,200	3,700	1,800	1,889	1,220	1,600	2,600	1,870	2,100
Do	169	3,000	1,900	4,200	1,600	1,250	3,250	1,400	2,050	3,250	1,800	1,950	1,760	1,800	2,600	2,050	1,600
Fall-plowed	163	3,440	2,100	3,900	2,150	1,300	2,650	1,750	2,050	3,450	1,800	2,000	1,450	1,800	3,100	1,150	1,550
Wheat:																	
Fall-plowed	164	2,690	2,200	3,600	2,600	1,250	5,880	550	2,250	3,450	1,900	1,630	2,130	2,050	2,050	2,580	1,650
Do	265	4,060	1,900	3,750	1,350	800	3,300	2,150	2,650	4,550	1,900	1,850	1,520	2,100	3,050	2,750	1,750
Field B:																	
Wheat:																	
One-wayed	265	------	------	------	------	------	------	------	------	------	------	------	------	------	------	1,590	1,650

Previous crop and tillage treatment	Rotation number	Acre yields in—														Average
		1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	
Field A:																
Kafir:																
Spring-plowed	160	1,500	810	2,960	1,670	2,160	1,550	2,320	3,160	490	820	390	480	940	3,300	1,861
Do	162	1,500	980	2,910	1,880	1,880	1,550	2,700	2,980	660	1,310	310	630	1,220	3,330	1,844
Do	167	1,850	910	2,690	2,000	2,790	1,410	3,040	3,230	860	1,200	480	770	1,580	4,610	2,231
Do	284	2,000	740	3,380	1,690	2,400	1,400	2,620	3,630	860	1,480	690	680	1,160	7,550	2,050
Do	285	1,500	700	2,500	1,650	2,400	1,080	2,510	3,440	740	1,580	470	740	1,390	4,200	1,946
Do	[1] 285′	1,500	720	2,870	1,410	2,040	1,410	2,260	3,140	780	1,130	680	630	1,040	3,300	1,755
Fall-plowed	161	1,600	900	2,520	1,810	2,170	1,260	2,620	3,360	800	1,170	380	680	1,300	4,000	1,970
Milo:																
Spring-plowed	166	1,750	1,090	2,710	1,830	2,690	1,590	2,770	2,790	670	1,190	490	700	1,630	4,740	2,132
Do	169	1,900	1,020	3,220	2,040	2,150	1,190	2,830	3,300	810	1,170	390	690	1,330	3,680	2,039
Fall-plowed	163	2,200	1,070	3,010	1,970	2,130	1,140	3,070	3,240	830	1,430	500	760	1,720	3,930	2,088
Wheat:																
Fall-plowed	164	1,700	1,120	2,670	1,610	3,060	1,750	2,960	3,180	740	1,200	510	770	1,680	5,480	2,230
Do	265	1,600	820	1,810	1,820	3,220	1,450	2,350	3,500	1,060	1,720	550	900	2,120	4,250	2,220
Field B:																
Wheat:																
One-wayed	265	2,000	690	2,340	2,000	2,430	1,330	2,700	2,830	950	1,200	600	680	1,600	3,280	1,742

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[1] 1 mark (′) on a number means 1 replication of the rotation designated by that number.

Table 33.—*Annual, average, and total hay yields in pounds per acre from cowpeas, winter rye, and Sudan grass in manured and unmanured rotations, field A, Woodward, Okla., 1915–37*

Year	Crop and rotation number							
	Cowpeas		Winter rye		Sudan grass		Annual total for cowpeas, rye and sudan	
	[1] 84	[2] 87	[1] 84	[2] 87	[1] 84	[2] 87	[1] 84	[2] 87
1915	2, 720	2, 555	5, 200	4, 950	4, 890	5, 600	12, 810	13, 105
1916	1, 640	1, 510	2, 050	1, 600	4, 000	3, 650	7, 690	6, 760
1917	1, 400	1, 500	1, 000	700	1, 650	2, 150	4, 050	4, 350
1918	750	550	1, 600	1, 500	1, 530	1, 810	3, 880	3, 860
1919	3, 250	3, 050	3, 400	3, 500	2, 000	2, 150	8, 650	8, 700
1920	1, 900	1, 650	1, 750	1, 150	6, 600	6, 950	10, 250	9, 750
1921	3, 350	3, 350	3, 900	4, 900	5, 450	6, 400	12, 700	14, 650
1922	1, 200	1, 300	2, 150	2, 100	2, 450	2, 250	5, 800	5, 650
1923	800	1, 250	1, 840	2, 160	2, 150	1, 750	4, 790	5, 160
1924	2, 800	3, 150	1, 900	2, 900	4, 850	4, 950	9, 550	11, 000
1925	1, 270	1, 930	1, 050	650	3, 530	4, 350	5, 850	6, 930
1926	1, 600	2, 350	3, 800	4, 100	5, 530	6, 300	10, 930	12, 750
1927	4, 130	4, 350	1, 800	3, 500	4, 400	6, 350	10, 330	14, 200
1928	1, 930	1, 600	935	1, 250	2, 600	2, 530	5, 465	5, 380
1929	1, 470	1, 650	2, 670	2, 700	2, 970	4, 410	7, 110	8, 760
1930	1, 120	1, 590	1, 400	1, 650	1, 750	1, 750	4, 270	4, 990
1931	1, 270	1, 550	1, 800	2, 880	2, 670	4, 560	5, 740	8, 990
1932	2, 070	2, 500	2, 650	3, 900	2, 670	3, 250	7, 390	9, 650
1933	1, 900	2, 290	1, 200	1, 400	2, 590	4, 250	5, 690	7, 940
1934	1, 400	1, 450	1, 410	1, 710	1, 550	2, 440	4, 360	5, 600
1935	1, 330	1, 450	870	1, 650	2, 030	3, 000	4, 230	6, 100
1936	570	600	1, 400	1, 850	1, 730	2, 100	3, 700	4, 550
1937	3, 410	2, 770	3, 400	3, 700	2, 530	3, 500	9, 340	9, 970
Average	1, 882	1, 998	2, 138	2, 452	3, 136	3, 759	7, 155	8, 208

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[1] Unmanured.
[2] Manured.

TABLE 34.—*Average nitrogen and carbon content, and carbon-nitrogen ratio of soil under various rotations, Woodward, Okla., 1947* [1]

Crop	Plots	Rotation [2]	Year started	Nitrogen		Carbon		Ratio of carbon to nitrogen at—	
				0 to 6 inches	6 to 12 inches	0 to 6 inches	6 to 12 inches	0 to 6 inches	6 to 12 inches
CONTINUOUS ROW CROPS, PLOWED									
				Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Corn	A, B	C. C	1914	0.036	0.042	0.38	0.40	10.6	9.5
Milo	A, B	C. C	1914	.032	.042	.34	.40	10.6	9.5
Do	B′ [3]	C. C	1918	.026	.034	.25	.32	9.6	9.4
Kafir	A, B	C. C	1914	.032	.044	.34	.44	10.6	10.0
Broomcorn	A, B	C. C	1914	.028	.038	.30	.40	10.7	10.5
Sorgo	A, B	C. C	1914	.028	.038	.30	.37	10.7	9.7
Mean				0.031	0.040	0.32	0.39	10.3	9.8
CONTINUOUS ROW CROPS, MANURED AND PLOWED									
Milo	H	C. C	1918	0.035	0.038	0.40	0.37	11.4	9.7
Kafir	H	C. C	1918	.042	.046	.43	.49	10.2	10.6
Mean				0.038	0.042	0.42	0.43	10.8	10.2
ALTERNATE ROW CROPS, AND FALLOW									
Corn	C, D	C. C	1914	0.028	0.034	0.26	0.32	9.3	9.4
Milo	C, D	C. C	1914	.024	.031	.24	.29	10.0	9.4
Do	A, B	297	1918	.025	.031	.26	.30	10.4	9.7
Kafir	C, D	C. C	1914	.026	.034	.27	.31	10.4	9.1
Broomcorn	C, D	C. C	1914	.028	.034	.32	.35	11.4	10.3
Sorgo	C, D	C. C	1914	.022	.030	.23	.29	10.4	9.7
Mean				0.026	0.032	0.26	0.31	10.0	9.7
KAFIR AND COWPEAS, BOTH SPRING-PLOWED									
Kafir and cowpeas	A, B	285	1918	0.022	0.038	0.22	0.36	10.0	9.5

KAFIR, AND COWPEAS PLOWED UNDER (SPRING-PLOWED FOR COWPEAS)

Kafir and cowpeas	A, B	286	1918	0.028	0.034	0.29	0.34	10.4	10.0

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[1] As there was no virgin area representative of the sites of the plot rotations, no estimate could be made of variations resulting from differences in locations, and least significant differences between rotations were not computed.

[2] C. C. indicates continuous-cropping or alternate-cropping groups.

[3] 1 mark (′) on a capital letter means 1 replication of the C. C. plot designated by that letter.

TABLE 35.—*Average percentage of nitrogen in the first foot of soil in 1914, and in 1947 under different cropping treatments, Woodward, Okla.*

Cropping treatment	Year started	Number of plots	Nitrogen content in— 1914	Nitrogen content in— 1947	Change in nitrogen content [1]
			Percent	*Percent*	*Percent*
Continuous row crops	[2] 1914	11		0.036	−55
Continuous row crops, manured	1918	2		.040	−50
Alternate row crops, and fallow	[3] 1914	12		.029	−64
Row crops and cowpeas	1918	2		0.030	−62
Row crops and cowpeas, green manure	1918	2		.031	−61
Virgin sod		3	0.08		

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[1] Changes are based on the assumption that all treatments contained the same amount of nitrogen in 1914 as the virgin sod.

[2] 1 of these plots was established in 1918.

[3] 2 of these plots were established in 1918.

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